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Animal Waste Utilization on Cropland and Pastureland. A Manual for Evaluating Agronomic and Environmental Effects

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Engineering and agronomic techniques to predict and control the volume of nutrients and chemical oxygen demand leaving the application sites, caused by the application of animal wastes, are described. Methodology was developed to enable the user to identify the pollutant loads for different management practices and to select the best management practice for a given site or region. Engineering, agronomic and economic factors are included in the decision process. The information is presented in the form of regional maps, decision flow charts, tables, graphs, example problems and brief technical highlights.

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ANIMAL WASTE UTILIZATION ON CROPLAND AND PASTURELAND

A Manual for Evaluating Agronomic and Environmental Effects

Authored by scientists of the Science and Education Administration, USDA.

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FOREWORD

In the years ahead, U.S. farmers will have to increase food and fiber production to meet domestic and world needs. Increased production will require use of all available resources and more intensive management of available cropland. Existing and new production technology should be integrated into management systems that will ensure sustained crop production and simultaneously protect or enhance the quality of our environment. These management systems should include elements that maximize beneficial use of animal wastes and minimize potential discharge of pollutants into our Nation's waters as a result of their production or use. To assist U.S. farmers in meeting these goals, the Science and Education Administration (USDA) and the Office of Research and Development (EPA) are issuing this informational report.

This technical report was designed for use in the development of management guidelines and should be used in conjunction with local expertise. The scope of this report is limited by available information on use and pollution potential of animal waste and is based on current understanding. The scope will be expanded and the contents updated as additional information becomes available from ongoing research.

This joint USDA/EPA report is published as partial fulfillment of provisions of the Clean Water Act (Public Law 92–500 as amended by Public Law 95–217), which reaffirms the objective of restoring and maintaining the quality of the Nation's waters.

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Agricultural Research, Science and
Education Administration
U.S. Department of Agriculture

Stephen J. Gage, Assistant Administrator
for Research and Development,
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Section 1

INTRODUCTION

The spreading of livestock and poultry manures[1] and bedding on land has been a convenient and long-used disposal method that benefits the soil. For proper animal waste management, one must consider the application methods, type and management of livestock or poultry, and many land, crop, and climatic factors. This manual describes and evaluates some of these variables.

Clean Water Act (Public Law 92–500 as amended by Public Law 95–217) reaffirms the objectives of restoring and maintaining the quality of the Nation's water. Section 208 of that act concerns nonpoint sources of water pollution such as might result from livestock and crop production. Increased emphasis is being placed on establishing guidelines that allow better use of livestock and poultry manures for crop production, yet minimize pollution problems. Area planners are concerned with area-wide analysis and development of guidelines, whereas farmers and other animal producers must adjust to area-wide decisions by choosing an effective and economic application technology. Farmers cannot make meaningful decisions until planners have developed nonpoint-runoff guidelines or designed alternative best management practices.

Area planners must first determine through water quality measurements whether an agricultural pollution water problem exists within any part of their area. Obviously, for areas where water quality is not a problem, no action is needed. A scheme for determining the major water polluting sources due to animal wastes and suggested procedures for assisting area planning personnel in identifying problems and developing recommended guidelines are presented in Section 2 under the subsection *Area Planning*.

Livestock and poultry industries are a significant part of the U.S. agricultural economy. Livestock inventory numbers in 1975 in the continental United States were about 11.1 million dairy cows, 43.7 million beef cows (144), 10.2 million beef feeders, 49.6 million swine (145), and 13.3 million sheep (146). Poultry inventory numbers in 1975 were 279.8 million layers, 586.5 million broilers, and 49.7 million turkeys (*4*).[2] These livestock and poultry void annually about 112 million tons of animal wastes (dry weight) (153). Some of this material is distributed directly to pastureland by cattle, sheep, and swine, with the rest, about 52 million tons, available for collection and application to land. After losses from the manure voided directly on pasture and rangeland, and from storage and waste-handling systems about 2.6, 1.0, and 2.3 million tons of nitrogen (N), phosphorus (P), and potassium (K), respectively, remain in the manure available for land application. (Note data in table 1 for 1974.)

U.S. agriculture uses about 9.2 million tons of chemical fertilizer N annually (31). Nitrogen available from voided animal manures would provide about 45% of that amount but only about 28% after allowing for losses. The amount of N lost depends on manure management practices (9).

Livestock and poultry are produced throughout the United States, but more intensively in some areas (126). If all animal wastes were uniformly distributed on cropland, however, only a few counties would have enough to meet N fertilizer needs. Where animal production is concentrated, proper manure management and application to land can reduce pollution and help maintain ecological balance because manures return to the soil some fertilizer elements removed in harvested crops.

Animal manures are beneficial because soil organisms decomposing the organic matter form humus

---

[1] The common, collective term *manure* denotes the fecal and urinary excretions of livestock and poultry as well as those subjected to biological changes and combined with such material as bedding, feed, soil, and precipitation. The term *animal waste* has essentially the same meaning as manure. These two terms will be used interchangeably in this manual.

[2] Numbers in parentheses refer to items listed in "References," p. 93.

TABLE 1.—*Estimated quantities of nitrogen (N), phosphorus (P), and potassium (K), distributed or available for application to land from livestock and poultry manures in the continental United States, 1974*[1]

Source	Manures dry weight	Percent recoverable [2]	Elements in manure		
			N	P	K
	Million tons		*Thousand tons*		
Dairy cows	23.6	86	575	138	707
Beef cows	40.7	5	890	370	807
Beef feeders	16.0	100	263	92	132
Swine	8.7	64	521	220	358
Sheep	3.4	50	103	38	163
Layers	3.3	100	92	68	68
Broilers	2.4	100	122	37	44
Turkeys	1.5	64	52	20	26
Total	99.6	—	2,618	983	2,305

[1] The United States Agricultural Census for 1974 and estimates of element losses in current management systems were used to compute the values (153).

[2] Includes any areas of production where manure may be collected for use elsewhere. Does not include manure deposited directly on pasture and rangeland by cattle, sheep, and swine.

and release various elements essential to plant life. The decomposing organic matter and humus improve soil tilth, increase water-holding capacity, reduce wind and water erosion, improve aeration, and promote the growth of beneficial soil organisms (115). The poorer the soil, the more animal waste can improve soil fertility.

Improper land-application methods may increase the concentration of nutrients in surface runoff from agricultural land. Runoff may transport nutrients, oxygen-demanding materials, and infectious agents into waterways (164). Excessive manure application rates may lead to nitrate pollution of both runoff and ground water or may increase soil salinity through accumulation of sodium and potassium salts. Excessive rates can also cause nutrient imbalance, resulting in poor crop growth or metabolic disorders such as grass tetany and fat necrosis in grazing animals (159, 160, 161, 163).

Many interdependent variables must be considered when developing a management plan for land application of livestock and poultry manures. For example, climate, soils, cropping systems, soil and water management, and quantity and characteristics of manures all interact to affect soil conditions and plant growth.

Experiments with manure-disposal methods range from applying high rates on land to treatment processes (16, 124). Many methods have not proved economical or practical. High rates on land, for instance, may cause pollution. Treatment processes, while stabilizing biological properties, reduce the N available for plants. A combination of economic and ecological concerns, therefore, has renewed interest in land application of animal wastes as fertilizers. Methods and time of land application, however, must be carefully selected to balance agricultural, economic, and ecological requirements.

Material in this manual is based on the contributions of many persons in the Environmental Protection Agency and in the Science and Education Administration; the Economics, Statistics, and Cooperatives Service; the Forest Service; and the Soil Conservation Service of the USDA. The Council for Agricultural Science and Technology, Ames, Iowa, provided a highly professional and constructive review by 14 scientists and workers in the field of animal waste management.

Section 2

USE OF THE MANUAL

Manual Objectives

The objectives of this manual are threefold:

- Provide information for applying animal wastes to land in terms of agronomic benefit and/or pollution potential.
- Provide basic information to enable planners to reduce or control nonpoint pollution from animal wastes applied to land.
- Provide sufficient information to enable planners to integrate the many variables into beneficial land-application systems.

These objectives will be achieved when the procedures provided in this manual are used by planners in conjunction with groups of specialists to develop the best management practices for State and local areas. Specialists include farmers, engineers, agronomists, animal scientists, hydrologists, soil scientists, and economists.

This manual is to aid planners charged with meeting legal requirements regarding water pollution from nonpoint agricultural sources caused by use of livestock and poultry manures on land *if that is a problem in a particular instance*. These planners could be directly involved in the Section 208 planning process or with other environmental planning efforts. Included are guidelines for choosing the most appropriate manure management practice on specific crops and soils. It does not establish pollution control limits or specific criteria for a control plan. Some land-application practices cause fewer environmental problems than others, but it is not reasonable to conceive of plans to anticipate all possible risks. *Because manure-management practices vary throughout the country, no single group of control measures can be used for every field, nor will the information presented be useful in all areas.*

Manual Procedures

Area Planning

Suggested procedures to help area planning personnel identify problems and develop recommended guidelines are given in figure 1, table 2. and Sample Problem 1. The Section 208 area planner must first determine, through water-quality measurements, whether a water-quality problem exists due to agricultural pollution and whether it is from nonpoint or point sources. In areas where water quality does not meet minimum standards, the major polluting sources must be determined (see fig. 1). This manual does not provide maximum acceptable runoff values for environmental quality. These limits are to be set by local or other planners in conjunction with other pollutant sources in the planning area.

The polluting sources may be point, nonpoint, or both. This manual provides suggestions and methodology for identifying nonpoint sources. Point sources, such as large feedlots or dairy farms, which drain directly into streams, are usually self-evident and should be handled through existing regulations.

When the pollution source is uncertain, which may often be the situation, the next step is to examine the number, type, and size of livestock and poultry production units in the area. Figure 2 presents total manure production after losses from storage and handling and figure 3 the amount of manure economically collectible by county for the continental United States in 1974. More recent county data are not available for animal numbers for the United States. Current estimates of manure production can be made by multiplying local livestock and poultry numbers by the coefficients in Appendix tables 1 and 2. County units can be summed to Land Resource Area size which, along with data on tillable land use by crops, will give an estimate of the distribution and concentration of manure. Land Resource Regions and Land Resource Areas of the United States are given in figure 4, and details on their cropping are given in Austin (7). Local data on land use can be obtained from Soil Conservation Service and university and extension offices. Table 2 is a checklist of the kinds of information needed by an area planner to identify problems and recommend guidelines to control agriculturally related, nonpoint pollution. Current waste handling and treatment practices for an area can be obtained from university and extension offices, and a summary for geographic regions is given in table 3 (p. 13).

Given the foregoing information, the area planner will be able to identify those production units most likely responsible for a pollution problem. The planner should then evaluate the environmental and economic effects of alternative waste-handling practices that might be specified for these units in new regulatory guidelines. An evaluation of the environmental effects and some of the manure management problems are illustrated in Sample Problem 1, beginning on page 14.

Planners should have the goal of minimizing nonpoint pollution with the least economic hardship on the livestock industry, the agricultural community (farmers, input suppliers, and the processing/marketing system), and society. Farmers will view the problem differently. Given limits on surface runoff or the specification of alternative best management practices, they will ask: "What is the least cost technology to obtain maximum utilization of the manure?" This manual introduces economic con-

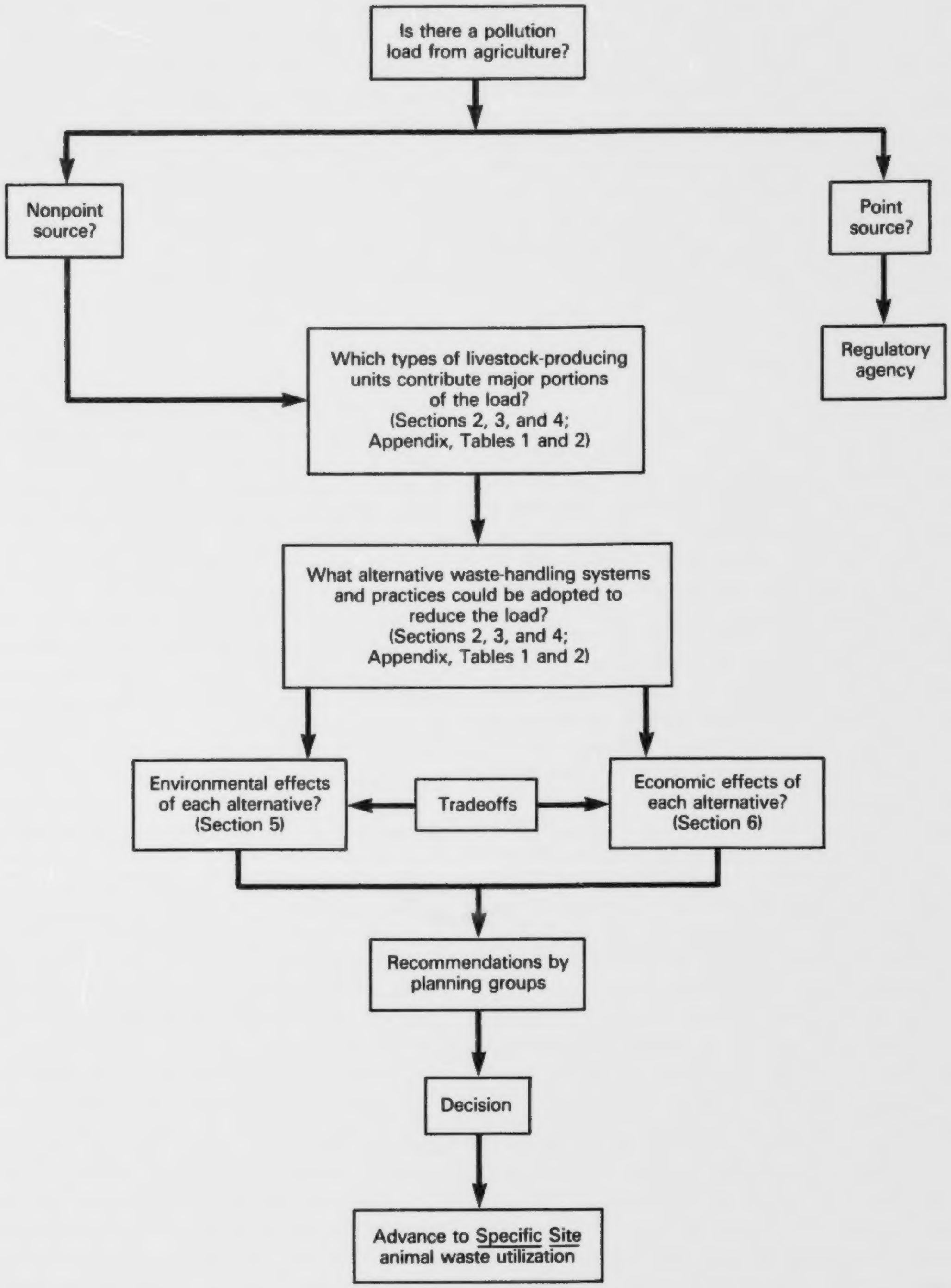

Is there a pollution load from agriculture?
Nonpoint source?
Point source?
Regulatory agency
Which types of livestock-producing units contribute major portions of the load? (Sections 2, 3, and 4; Appendix, Tables 1 and 2)
What alternative waste-handling systems and practices could be adopted to reduce the load? (Sections 2, 3, and 4; Appendix, Tables 1 and 2)
Environmental effects of each alternative? (Section 5)
Tradeoffs
Economic effects of each alternative? (Section 6)
Recommendations by planning groups
Decision
Advance to Specific Site animal waste utilization

FIGURE 1.—Suggested procedure for area planners developing animal waste utilization guidelines.

cepts which need to be considered in the formulation of animal waste management plans. However, it does not provide for a complete economic analysis but lays the groundwork for a subsequent manual of that nature.

Specific Site Planning

General procedures for use of this manual to utilize animal wastes on specific sites are shown on figure 5. The manual contains information and procedures for estimating quantity and quality of manures, land application rates, environmental effects, and the nature but not magnitude of economic impacts. Values for chemical concentrations in runoff are based on results from small field studies, and interpretations must be projected judiciously to large areas. Worksheets with instructions are used to work sample problems that illustrate methods of evaluating utilization of poultry and livestock manures. Each section contains one or two worksheets. Combined, they illustrate a solution to Sample Problem 2. Examination of figure 5, the statement of the Sample Problem 2, and Worksheet 1 (pp. 9, 15, and 16) will help the user understand the descriptive nature and purpose of the worksheets.

TABLE 2.—*Example checklist of information needed by an area planner to identify problems and recommend guidelines to control agriculturally related, nonpoint pollution*

General Information

A. ________What are the maximum acceptable runoff values for environmental quality?
B. ________Is there a pollution load from agriculture?
C. ________Is the pollution load from agriculture a significant fraction of the total load?
D. ________Are all point sources of agriculturally related pollution controlled at present?
E. ________What are the major types of livestock and poultry enterprises in the area?
F. ________Which animal enterprises produce collectible manures?

Specific Data

A. Animal Data
  1. ________Major animal types
  2. ________Numbers of each animal type
  3. ________Kinds of manure management
  4. ________Amounts of manure collectible for each animal type and management
  5. ________Kinds of changes possible in manure management
  6. ________Changes possible in amounts of manure collectible for each animal type and management

B. Land Use Data
  1. ________Present land uses and maximum areas available for manure utilization
  2. ________Areas of land now receiving manure
  3. ________Common land application practices and techniques
  4. ________Common rates of manure application
  5. ________Suggested changes in practices and techniques of manure utilization
  6. ________Distances manure would need to be transported to change manure distribution

C. Environmental Data
  1. ________Present water quality
  2. ________Water quality standards needed
  3. ________Contribution to present water quality by agriculturally related, nonpoint pollution
  4. ________Projected water quality improvement due to change in manure utilization

D. Economic Data
  1. ________Distances and costs to move and utilize manures at present
  2. ________Distances and costs to move and utilize manures when changes are instituted
  3. ________Changes and costs in allied and supportive industries of the agricultural community and in society caused by guideline institution

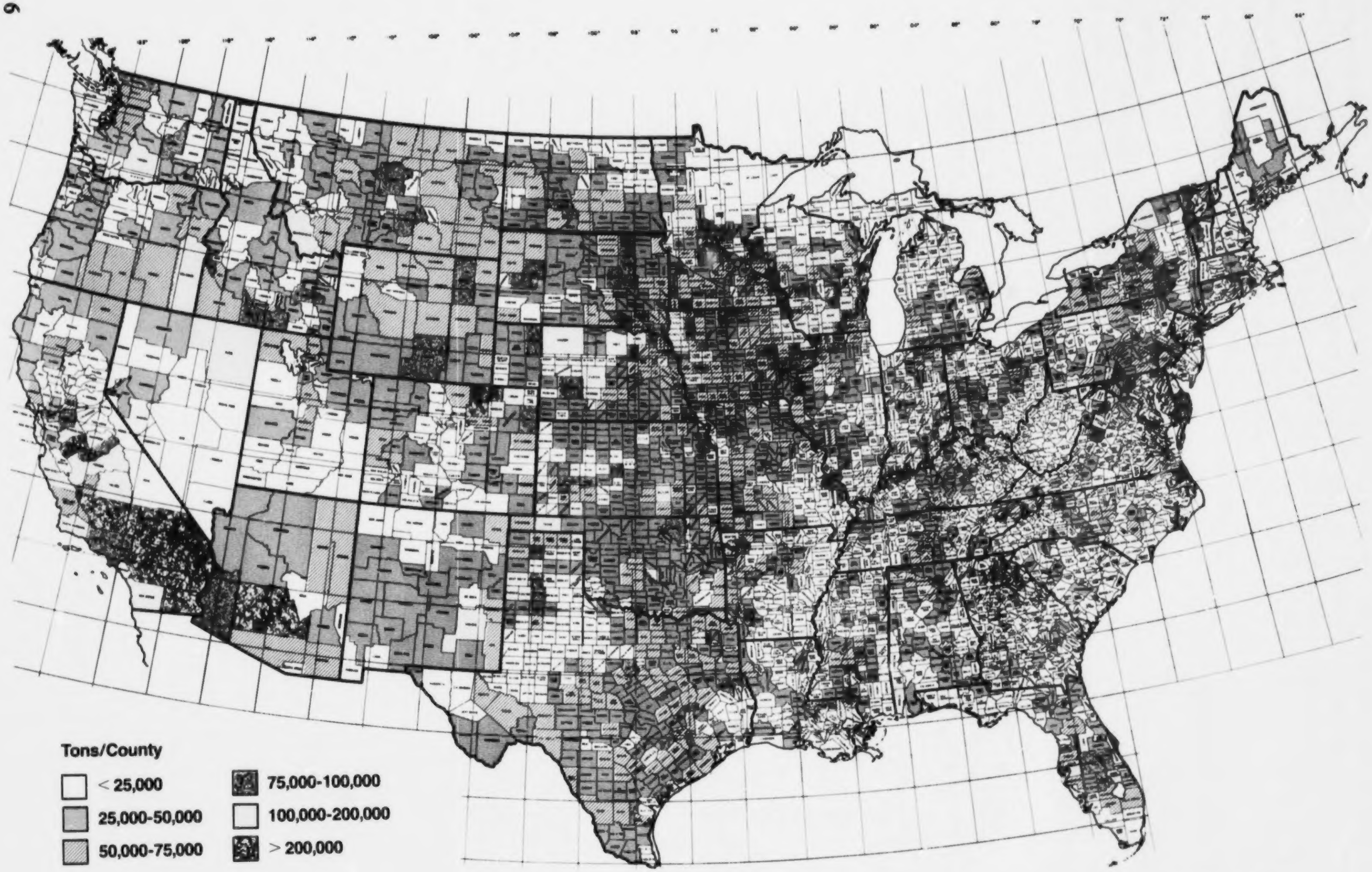

Tons/County
☐ < 25,000
▨ 25,000-50,000
▨ 50,000-75,000
▨ 75,000-100,000
☐ 100,000-200,000
▨ > 200,000

FIGURE 2.—Manure production by livestock and poultry after losses from storage and waste-handling systems in the continental United States, 1974.

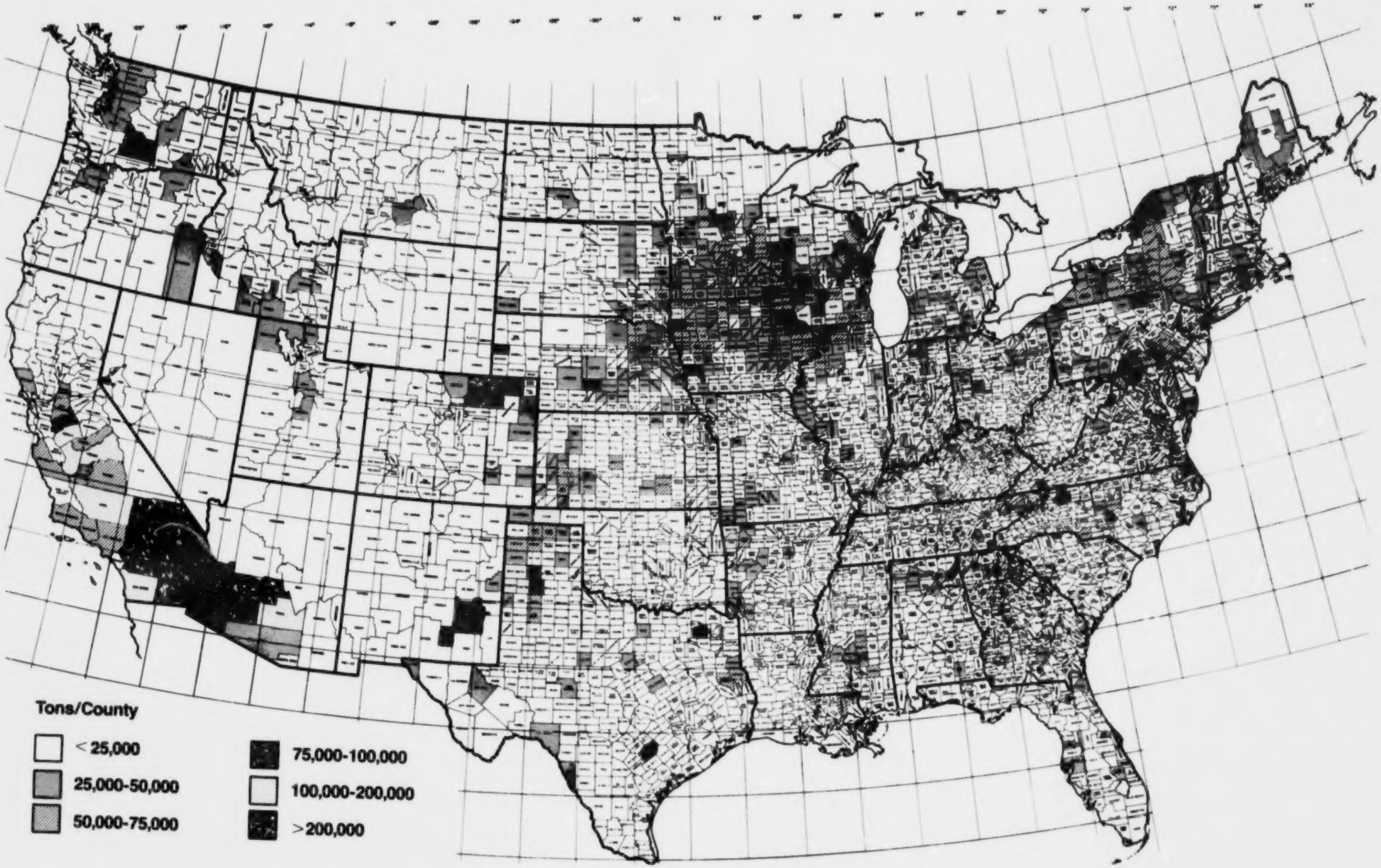

Tons/County
< 25,000
25,000-50,000
50,000-75,000
75,000-100,000
100,000-200,000
>200,000

FIGURE 3.—Manure from livestock and poultry which is economically collectible in the continental United States, 1974.

A
F
L
M
J
P
T
93
56
57
102
20
20
20
SCALE
50 0 50 100 150 200 250 300 Miles

Land Resource Regions and Major Land Resource Areas Of The United States (exclusive of Alaska and Hawaii)

A **Northwestern Forest, Forage, And Specialty Crop Region**
1 Northern Pacific Coast Range and Valleys
2 Willamette and Puget Sound Valleys
3 Olympic and Cascade Mountains (Western Slope)
4 California Coastal Redwood Belt
5 Siskiyou-Trinity Area

Northwestern Wheat and Range Region
6 Cascade Mountains (Eastern Slope)
7 Columbia Basin
8 Columbia Plateau
9 Palouse and Nez Perce Prairies
10 Upper Snake River Lava Plains and Hills
11 Snake River Plains
12 Lost River Valleys and Mountains
13 Eastern Idaho Plateaus

California Subtropical Fruit, Truck, And Specialty Crop Region
14 Central California Valleys
15 Central California Coast Range
16 California Delta
17 Sacramento and San Joaquin Valleys
18 Sierra Nevada Foothills
19 Southern California Coastal Plain
20 Southern California Mountains

Western Range and Irrigated Region
21 Klamath and Shasta Valleys and Basins
22 Sierra Nevada Range
23 Malheur High Plateau
24 Humboldt Area
25 Owyhee High Plateau
26 Carson Basin and Mountains
27 Fallon-Lovelock Area
28 Great Salt Lake Area
29 Southern Nevada Basin and Range
30 Sonoran Basin and Range
31 Imperial Valley
32 Northern Intermountain Desertic Basins
33 Semiarid Rocky Mountains
34 Central Desertic Basins, Mountains, and Plateaus
48 (See E)
35 Colorado and Green Rivers Plateaus
36 New Mexico and Arizona Plateaus and Mesas
37 San Juan River Valley Mesas and Plateaus

Western Range and Irrigated Region (Continued)
38 Black, Hualpai, and Cerbat Mountains
39 Arizona and New Mexico Mountains
40 Central Arizona Basin and Range
41 Southeastern Arizona Basin and Range
42 Southern Desertic Basins, Plains, and Mountains

E **Rocky Mountain Range and Forest Region**
43 Northern Rocky Mountains
44 Northern Rocky Mountain Valleys
45 Alpine Meadows and Rockland
46 Northern Rocky Mountain Foothills
47 Wasatch and Uinta Mountains
48 Southern Rocky Mountains
49 Southern Rocky Mountain Foothills
50 San Luis Valley
51 High Intermountain Valleys

F **Northern Great Plains Spring Wheat Region**
52 Brown Glaciated Plain
53 Dark Brown Glaciated Plain
54 Rolling Soft Shale Plain
55 Black Glaciated Plains
56 Red River Valley of the North
57 Western Minnesota Forest – Prairie Transition

Western Great Plains Range and Irrigated Region
58 Northern Rolling High Plains
59 Northern Smooth High Plains
60 Pierre Shale Plains and Badlands
61 Black Hills Foot Slopes
62 Black Hills
63 Rolling Pierre Shale Plains
64 Mixed Sandy and Silty Tableland
65 Nebraska Sand Hills
66 Dakota-Nebraska Eroded Tableland
67 Central High Plains
68 Irrigated Upper Platte River Valley
69 Upper Arkansas Valley Rolling Plains
70 Pecos – Canadian Plains and Valleys

Central Great Plains Winter Wheat and Range Region
71 Central Nebraska Loess Hills
72 Central High Tableland
73 Rolling Plains and Breaks
74 Central Kansas Sandstone Hills
75 Central Loess Plains
76 Bluestem Hills
77 Southern High Plains
78 Central Rolling Red Plains
79 Great Bend Sand Plains
80 Central Rolling Red Prairies

Southwestern Plateaus and Plains Range and Cotton Region
81 Edwards Plateau
82 Texas Central Basin
83 Rio Grande Plain

J **Southwestern Prairies Cotton and Forage Region**
84 Cross Timbers
85 Grand Prairie
86 Texas Blackland Prairie
87 Texas Claypan Area

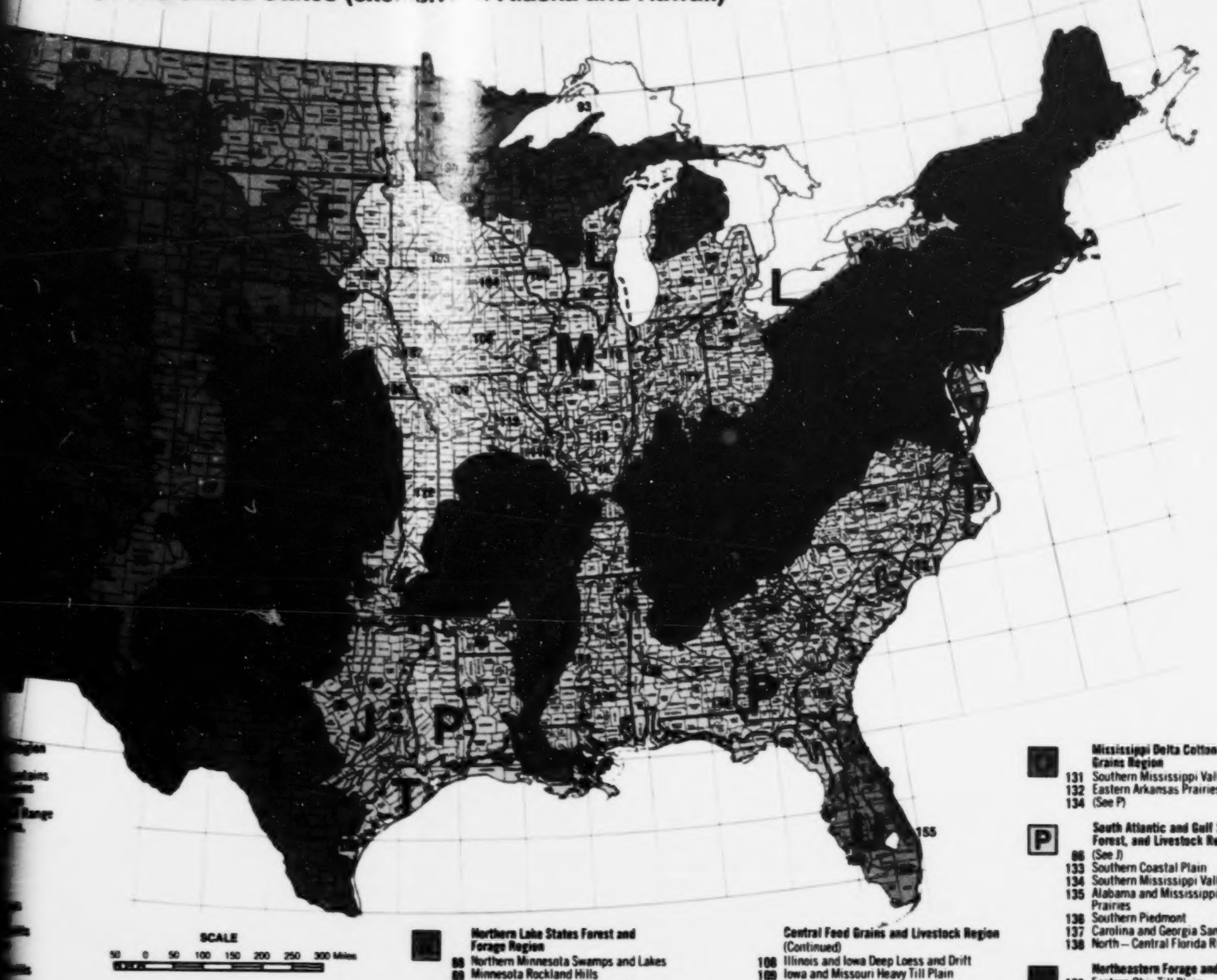
Northern Lake States Forest and Forage Region
88 Northern Minnesota Swamps and Lakes
89 Minnesota Rockland Hills
90 Central Wisconsin and Minnesota Thin Loess and Till
91 Wisconsin and Minnesota Sandy Outwash
92 Superior Lake Plain
93 Northern Michigan and Wisconsin Stony, Sandy, and Rocky Plains and Hills
94 Northern Michigan Sandy Drift

L **Lake States Fruit, Truck, and Dairy Region**
95 Southeastern Wisconsin Drift Plain
96 Western Michigan Fruit Belt
97 Southwestern Michigan Fruit and Truck Belt
98 Southern Michigan Drift Plain
99 Erie – Huron Lake Plain
100 Erie Fruit and Truck Area
101 Ontario – Mohawk Plain

M **Central Feed Grains and Livestock Region**
102 Loess, Till, and Sandy Prairies
103 Central Iowa and Minnesota Till Prairies
104 Eastern Iowa and Minnesota Till Prairies
105 Northern Mississippi Valley Loess Hills
106 Nebraska and Kansas Loess – Drift Hills
107 Iowa and Missouri Deep Loess Hills

FIGURE 4.—Land resource regions and major Land Resource Areas of the continental United Stat

Land Resource Regions an Maj Land Resource Areas Of The United States (exc siv f Alaska and Hawaii)



Central Great Plains Winter Wheat and Range Region
71 Central Nebraska Loess Hills
72 Central High Tableland
73 Rolling Plains and Breaks
74 Central Kansas Sandstone Hills
75 Central Loess Plains
76 Bluestem Hills
77 Southern High Plains
78 Central Rolling Red Plains
79 Great Bend Sand Plains
80 Central Rolling Red Prairies

Southwestern Plateaus and Plains Range and Cotton Region
81 Edwards Plateau
82 Texas Central Basin
83 Rio Grande Plain

J **Southwestern Prairies Cotton and Forage Region**
84 Cross Timbers
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87 Texas Claypan Area

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L **Lake States Fruit, Truck, and Dairy Region**
95 Southeastern Wisconsin Drift Plain
96 Western Michigan Fruit Belt
97 Southwestern Michigan Fruit and Truck Belt
98 Southern Michigan Drift Plain
99 Erie – Huron Lake Plain
100 Erie Fruit and Truck Area
101 Ontario – Mohawk Plain

M **Central Feed Grains and Livestock Region**
102 Loess, Till, and Sandy Prairies
103 Central Iowa and Minnesota Till Prairies
104 Eastern Iowa and Minnesota Till Prairies
105 Northern Mississippi Valley Loess Hills
106 Nebraska and Kansas Loess – Drift Hills
107 Iowa and Missouri Deep Loess Hills

Central Feed Grains and Livestock Region (Continued)
108 Illinois and Iowa Deep Loess and Drift
109 Iowa and Missouri Heavy Till Plain
110 Northern Illinois and Indiana Heavy Till Plain
111 Indiana and Ohio Till Plain
112 Cherokee Prairies
113 Central Claypan Areas
114 Southern Illinois and Indiana Thin Loess and Till Plain
115 Central Mississippi Valley Wooded Slopes

East and Central General Farming And Forest Region
112 (See M)
116 Ozark Highland
117 Boston Mountains
118 Arkansas Valley and Ridges
119 Ouachita Mountains
120 Kentucky and Indiana Sandstone and Shale Hills and Valleys
121 Kentucky Bluegrass
122 Highland Rim and Pennyroyal
123 Nashville Basin
124 Western Allegheny Plateau
125 Cumberland Plateau and Mountains
126 Central Allegheny Plateau
127 Eastern Allegheny Plateau and Mountains
128 Southern Appalachian Ridges and Valleys
129 Sand Mountain
130 Blue Ridge

Mississippi Delta Cotton and Feed Grains Region
131 Southern Mississippi Valley Alluvium
132 Eastern Arkansas Prairies
134 (See P)

P **South Atlantic and Gulf Slope Cash Crop Forest, and Livestock Region**
86 (See J)
133 Southern Coastal Plain
134 Southern Mississippi Valley Silty Uplands
135 Alabama and Mississippi Blackland Prairies
136 Southern Piedmont
137 Carolina and Georgia Sand Hills
138 North – Central Florida Ridge

Northeastern Forage and Forest Region
139 Eastern Ohio Till Plain
140 Glaciated Allegheny Plateau and Catskill Mountains
141 Tughill Plateau
142 St. Lawrence – Champlain Plain
143 Northeastern Mountains
144 New England and Eastern New York Upland
145 Connecticut Valley
146 Aroostook Area

Northern Atlantic Slope Truck, Fruit, And Poultry Region
147 Northern Appalachian Ridges and Valleys
148 Northern Piedmont
149 Northern Coastal Plain

T **Atlantic and Gulf Coast Lowland Forest And Truck Crop Region**
150 Gulf Coast Prairies
151 Gulf Coast Marsh
152 Gulf Coast Flatwoods
153 Atlantic Coast Flatwoods

Florida Subtropical Fruit, Truck Crop, And Range Region
154 South Central Florida Ridge
155 Southern Florida Flatwoods
156 Florida Everglades and Associated Areas

4.—Land resource regions and major Land Resource Areas of the continental United States.

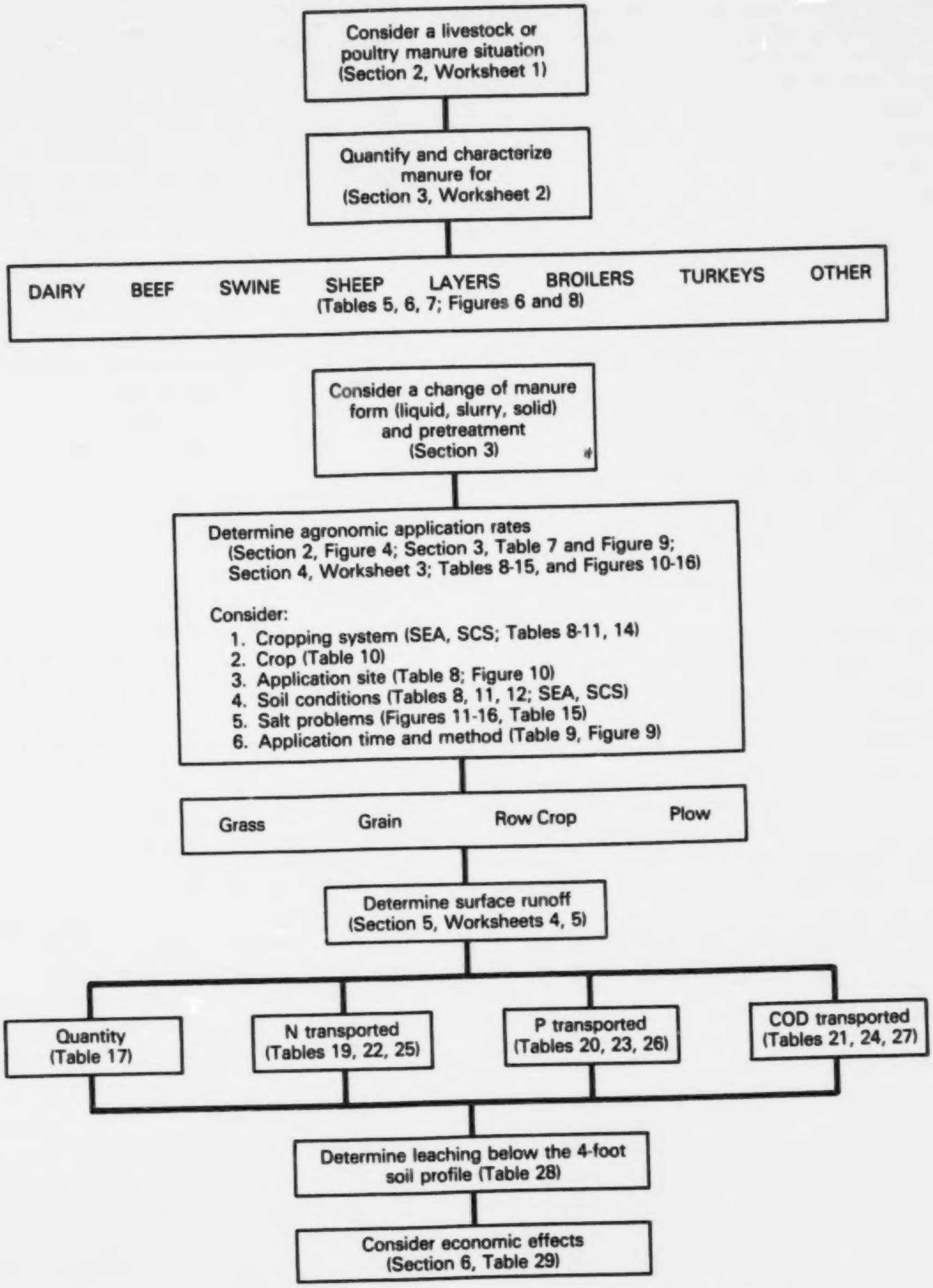

Consider a livestock or poultry manure situation (Section 2, Worksheet 1)
Quantify and characterize manure for (Section 3, Worksheet 2)
DAIRY
BEEF
SWINE
SHEEP
LAYERS
BROILERS
TURKEYS
OTHER
(Tables 5, 6, 7; Figures 6 and 8)
Consider a change of manure form (liquid, slurry, solid) and pretreatment (Section 3)
Determine agronomic application rates (Section 2, Figure 4; Section 3, Table 7 and Figure 9; Section 4, Worksheet 3; Tables 8-15, and Figures 10-16)
Consider:
1. Cropping system (SEA, SCS; Tables 8-11, 14)
2. Crop (Table 10)
3. Application site (Table 8; Figure 10)
4. Soil conditions (Tables 8, 11, 12; SEA, SCS)
5. Salt problems (Figures 11-16, Table 15)
6. Application time and method (Table 9, Figure 9)
Grass
Grain
Row Crop
Plow
Determine surface runoff (Section 5, Worksheets 4, 5)
Quantity (Table 17)
N transported (Tables 19, 22, 25)
P transported (Tables 20, 23, 26)
COD transported (Tables 21, 24, 27)
Determine leaching below the 4-foot soil profile (Table 28)
Consider economic effects (Section 6, Table 29)

FIGURE 5.—Master flow chart for evaluating animal wasteland application practices.

A "Glossary of Terms" and a "Reference Section" follow Section 6 (Economic Considerations). Particularly useful references are indicated by asterisks. The Appendix contains complete sample problems, explanation of constants and equations, and data on manure characteristics associated with different types of manure-handling systems. A set of blank worksheets, suitable for copying, is included at the end of the manual.

Summaries of the remaining sections that follow may be used to readily locate desired information and understand the manual's content without long perusal.

Quantity and Characteristics of Animal Wastes

(Section 3 begins on page 17.)

Factors that affect the quantity and characteristics of animal wastes are type and size of animal, climate, rations fed, and type of management system (9). Because manure characteristics vary, they should be determined by laboratory analyses if applicable local data are not available (42, 109, 112). Animal waste characteristics are similar for the same type of animal with similar manure management in the same climatic region. *Numbers in tables in this manual should be regarded as guides to possible values and not applicable to the entire United States.*

The climate at the feedlot determines, to some extent, the management system used, which, in turn, determines the characteristics of animal waste available for land application. For example, housed feedlots and outdoor lots with paved or unpaved lot surfaces with or without shelter are found in cold-humid, cool-humid, and occasionally, cool-arid climatic regions. (See figs. 6 and 7 for climatic regions and average annual precipitation.) Local data should be used for areas west of the 104th meridian and in swamp and forest areas because of erratic changes in climatological conditions. Geographic distribution of livestock and poultry management systems is provided in table 3. Land Resource Areas (LRA's, fig. 4, p. 8) are the basis for presentation of manure-management information. Detailed information about LRA's can be obtained from USDA Agriculture Handbook 296, "Land Resource Regions and Major Land Resource Areas of the United States" (7).

Land-Application Planning

(Section 4 begins on p. 24.)

The application site should be evaluated in terms of geographic area, surrounding land use, zoning requirements, topographic features, irrigation potential, and conservation practices. Application of animal wastes at agronomic rates (rates that provide for optimum crop production and that do not cause N and salt problems) will increase soil fertility (9 115). Livestock and poultry manures also affect soil tilth, water infiltration rates, and oxygen content. *Improper rates or application can pollute surface and ground water and reduce soil productivity* (164).

Proper application time is determined by climate, cropping and management systems, and form of animal waste. The form (solid, slurry, or liquid) determines the method of land application. Manure should be soil-incorporated immediately after application to avoid excessive N losses (84, 86, 116). The amount of N that should be applied to a specific site depends on the crop requirement, N available in the soil, and N losses by volatilization, leaching, denitrification, and runoff. Salts in applied animal wastes may increase soil salinity and lead to decreased yields and soil structure deterioration in low rainfall areas (106, 107, 109).

Water Quality

(Section 5 begins on p. 44.)

The quality of runoff or water percolating through soils may be changed by applied manure. Time, method, and rate of application; soil type; crop; and climate are influencing factors (124, 126).

Runoff quality is affected by the amounts of suspended sediments and soluble solids transported (164). *In this manual, N, P, and chemical oxygen demand (COD) contents in water solution, derived from applied livestock or poultry manure, excluding sediment, are used to indicate its change in quality. Bacteriological considerations are not included.*

Economic Considerations

(Section 6 begins on p. 85.)

Area-wide planners should carefully consider economic and societal as well as agronomic and environmental consequences of proposed nonpoint pollution abatement guidelines on land application of animal

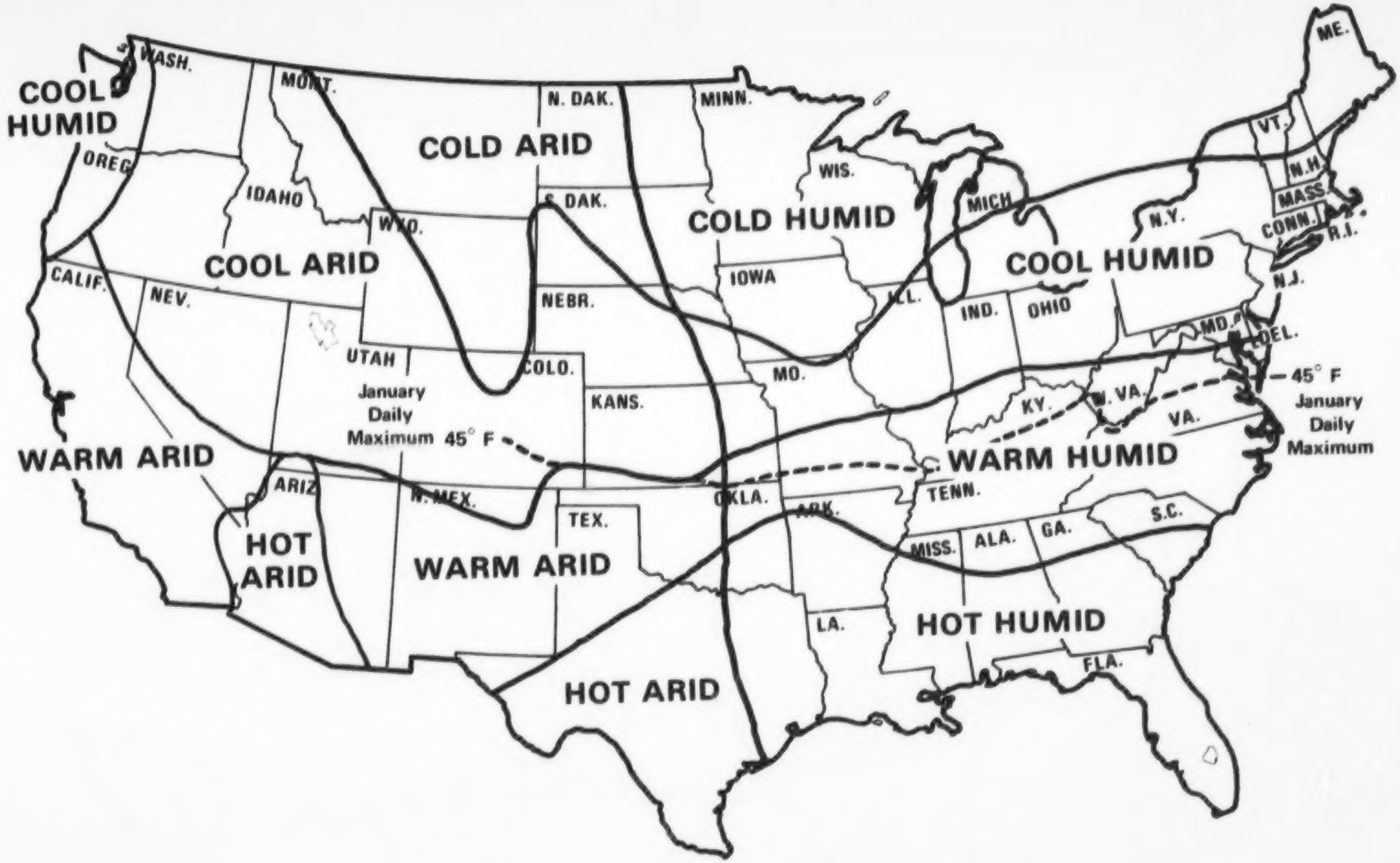
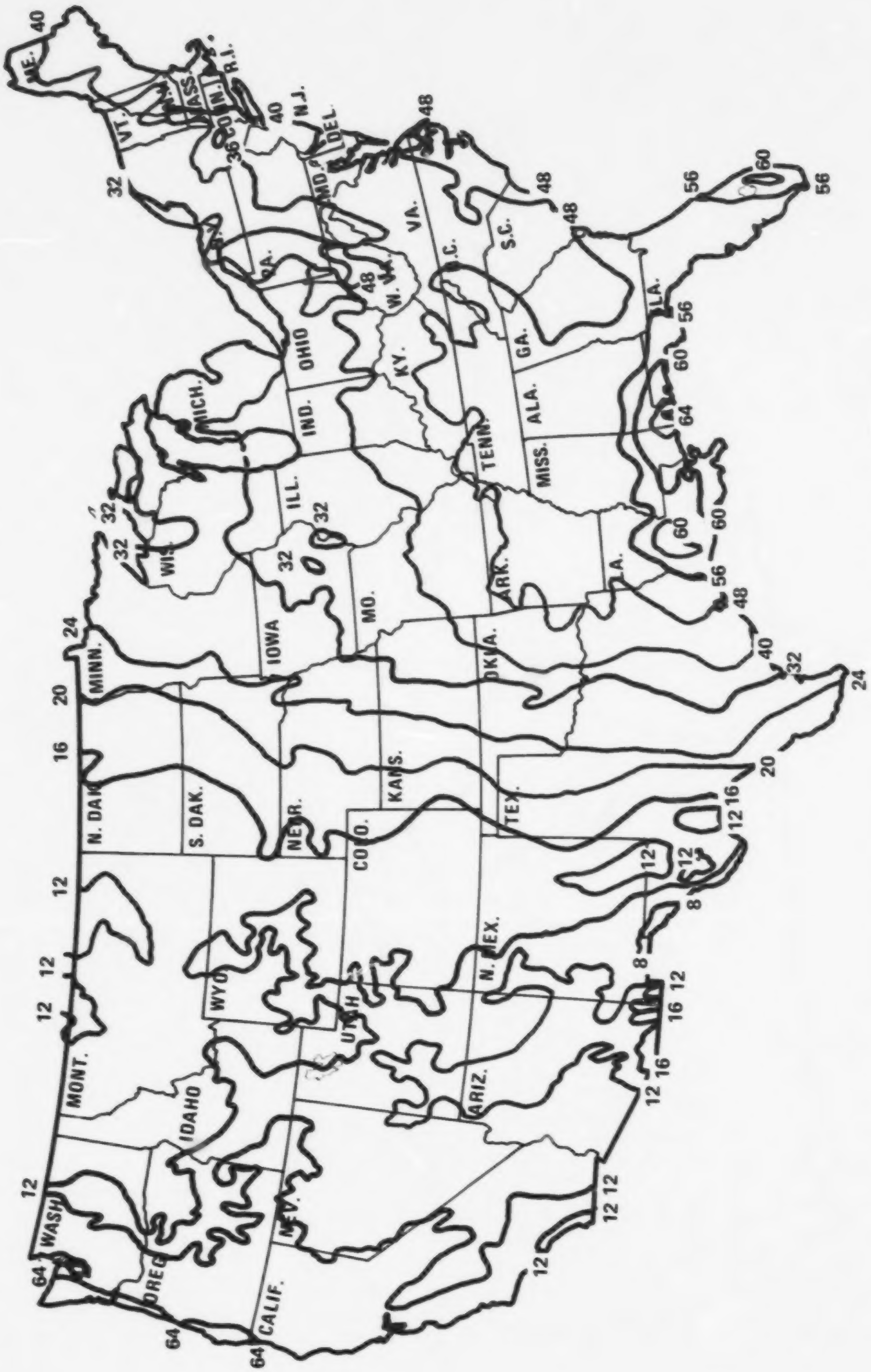

COOL HUMID
WASH.
OREG.
CALIF.
IDAHO
MONT.
NEV.
COOL ARID
WARM ARID
UTAH
WYO.
COLD ARID
N. DAK.
S. DAK.
NEBR.
COLO.
January Daily Maximum 45° F
ARIZ.
HOT ARID
N. MEX.
WARM ARID
TEX.
KANS.
OKLA.
HOT ARID
MINN.
WIS.
COLD HUMID
IOWA
MO.
ILL.
ARK.
LA.
MICH.
IND.
OHIO
COOL HUMID
KY.
W. VA.
VA.
WARM HUMID
TENN.
MISS.
ALA.
GA.
S.C.
HOT HUMID
FLA.
N.Y.
PA.
N.J.
MD.
DEL.
45° F January Daily Maximum
ME.
VT.
N.H.
MASS.
CONN.
R.I.

FIGURE 6.—Climatic regions of the continental United States.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NEV.
MONT.
WYO.
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ARIZ.
N. MEX.
COLO.
N. DAK.
S. DAK.
NEBR.
KANS.
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FLA.
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VA.
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12

FIGURE 7.—Average annual precipitation (in inches) for the continental United States.

TABLE 3.—*Estimated percentage distribution of livestock and poultry-management systems*[1]

Management Systems	Areas of the United States			
	%			
	Northeast and Lake States	*Southeast, Delta and Southern Plains*	*Mountains and Pacfiic*	*Corn Belt, Northern Plains, and Appalachian*
Dairy [2]				
Stanchion	63	7	4	22
Loose housing	6	38	14	34
Free Stall	26	22	35	41
Unpaved lot, limited housing	5	33	47	3

	West of 98th Meridan	*East of 98th Meridan*
Beef		
Breeding Stock		
Pasture	90	90
Other	10	10
Feeders		
Outdoor, unpaved lot without shelter [3]	85	56
Outdoor, unpaved lot with shelter [3]	4	31
Outdoor, paved lot with/without shelter [3]	11	13

	Major producing states [4]	All other States
Swine		
Pasture	25	50
Paved lot [5]	17	5
Unpaved lot [5]	41	40
Confined housing	17	5

	All regions
Sheep	
Breeding Stock	
Pasture	70
Confinement	30
Feeder Lambs	
Pasture	35
Outdoor, unpaved lot with shelter [6]	35
Outdoor, unpaved lot without shelter [6]	20
Outdoor, paved lot with/without shelter [6]	10

	All regions
Layers	
Caged with dry manure-holding system	70
Caged with flush, slurry, pit slurry	10
Loose housing with bedded floors	20

	All regions
Broilers	
Loose housing	100

TABLE 3.—*Estimated percentage distribution of livestock and poultry-management systems*[1]—Continued

Management Systems	Areas of the United States			
	%			
	Northeast and Lake States	*Southeast, Delta and Southern Plains*	*Mountains and Pacific*	*Corn Belt, Northern Plains, and Applachian*
			All regions	
Turkeys				
Outdoor or range (some with housing)			50	
Loose housing			50	

---

[1] Based on data developed by D. L. Van Dyne, Economics, Statistics, and Cooperatives Service, and C. B. Gilbertson, Science and Education Administration, U. S. Department of Agriculture, 1978 (153).

[2] 70% use stack or bunker storage; 20% use manure-holding ponds or lagoons; 10% use other methods of manure management.

[3] About 40% of the units require runoff-control facilities.

[4] Includes the Corn Belt and Lake States, South Dakota, Nebraska, Kansas, Texas, Kentucky, Tennessee, North Carolina, and Georgia.

[5] About 30% of the units require runoff-control facilities.

[6] About 20% of the units require runoff-control facilities.

manure. Economic consequences are especially important to individual livestock producers. This manual presents an overview of economic considerations. It does not provide the detailed information or suggested procedures necessary for a complete economic analysis. A manual to be published later will link the agronomic and environmental data with economic information and procedures to provide the basis for a more complete evaluation of best management practices to reduce nonpoint pollution from land application of animal wastes.

Sample Problem 1

Consideration of a hypothetical problem can illustrate points of evaluation and suggested guidelines to cope with nonpoint pollution in a given area. Nitrate-N (NO_3-N) in a small stream draining from a watershed is 50 parts per million (p/m). The location is a county in southwest Wisconsin in Land Resource Area 105 which has sixty 100-cow dairies (see figs. 2, 3, and 4, pp. 6, 7, and 8). At 30 of the dairies, manure is spread daily on meadows, pastures, and land that was fall plowed at an application rate of about 40 tons/acre (wet weight). At the other 30 dairies about 20 tons/acre are plowed down in both the spring and in the fall for corn silage. Local planners have decided that 50 p/m of NO_3-N is too high and want to reduce this level to near 10 p/m. What can be done to reduce this nitrate level? Are 20 tons/acre enough N for corn silage production?

Checking with the Science and Education Administration—Extension, we find the soil is 3.5% organic matter, which will supply about 70 pounds of N per acre per year. Then, from table 7 (p. 22), dairy manure removed daily is 13% total solids (TS), which is 3.2% N. So, 40 tons of manure contain 40 tons x 2,000 lb/ton x 0.13 (TS) x 0.032 (N) = 333.0 lb of N. Table 10 (p. 29) shows that bluegrass or timothy removes 60 lb of N per acre per year. Thus, the soil can supply the N required by the grass. Table 13 (p. 32) indicates 50% of the N applied is available the first year. Therefore, we would expect nitrate leaching from meadows and pastures where 40 tons/acre of manure were applied. Nitrate leaching can be reduced by applying manure to crops with higher N requirements. Table 10 (p. 29) shows that 8.7 tons/acre of corn dry matter (grain and stover) use 235 lb of N. Therefore, if this high yield of corn is harvested, little nitrate leaching would be expected.

When manure is applied at 20 tons/acre from storage, table 7 (p. 22) shows it is 18% TS, which is 2% N. Thus, 20 tons of stored manure contains 144 lb of N. If we assume this N is 50% available, then, we have 72 lb of N from manure and 70 lb of N from the soil, or 142 lb of N available. If the corn crop uses this at the rate of 235 lb/8.7 tons, shown in table 10 (p. 29), then, we have enough N to produce 142 lb/235 lb x 8.7 tons = 5.26 tons of corn dry matter. This indicates that little N leaching would be expected where 20 to 25 tons of manure are used on land for corn silage. If grain only is harvested, 15 to 20 tons of manure per acre will supply the N used.

Since nitrification is slow in cold weather, manure can be spread on corn land in the fall and winter without nitrate leaching. However, there may be spreading problems on wet land, and erosion and runoff losses must be considered. Table 19 (p. 50) shows the total N transported from land in LRA 105 to be small, so runoff losses are not considered a problem. Therefore, spreading on fall-plowed land would depend on soil moisture and the ability to move the spreader over the land without severe soil compaction.

Perhaps leaching is the major problem in the area, but runoff from grass is also a concern. For example, suppose the area of grass fertilized is about 1,400 acres. The grass will discharge about 4,760 lb of N per year (table 22, p. 60). While this is not much N, look at table 17: The runoff is less than 1 inch. Using 1 inch, the concentration is 15 p/m by spreading manure on the surface. (See Appendix "Parts per Million" for an explanation of this calculation.) If this practice were stopped, 15 p/m from these acres would be eliminated along with the leachate.

On the other hand, if this manure were used on about 2,800 acres of row crop with conservation measures, the area would discharge about 3,000 lb of N per year if surface applied. This would be a net savings to the stream of 1,760 lb of N, and 4,760 lb if incorporated. The concentration of N in the runoff from the row crop would be 2.2 p/m if surface applied, and zero if incorporated.

Planners interested in evaluating manure management problems will want to consider some of the following items, which are discussed in detail in Sections 3, 4, and 5:

1. Nitrogen available from manure and soil should not exceed crop needs.
2. Manure spread daily will apply the greatest amount of N to the land.
3. With daily spreading, erosion hazards may sometimes be high, i.e., when ground is frozen or soil is saturated from rainfall.
4. Surface spreading may leave manure subject to erosion and runoff losses, and volatile compounds may cause odor problems. Also N losses from volatile N compounds such as ammonia are usually greater with surface spreading than with injection or spreading and immediate incorporation.
5. Storing manure may allow leaching losses of N and K unless it is protected from the weather and stored in watertight bins or tanks.
6. Stored manure may be incorporated into the soil to minimize odors and loss of volatile N compounds, or it may be placed on meadows at the time when vigorous plant growth will use the nutrients most efficiently.
7. Storing manure allows more choices of crops on which to apply the manure.
8. When N is applied at very high rates, nitrate may leach into the ground water and flow into streams.

Sample Problem 2

A county agent in Rock County, Wis., wants to know if 25 tons (wet weight) of dairy manure per acre will supply enough nitrogen to corn, the application rate of runoff recommended, the acres of cropland needed, and how much N, P, and COD are lost from the application site if

–the dairy unit has 100 head of cows
–the dairy unit uses a stanchion barn
–the barn and paved lot manure is stored in a covered bunker
–lot runoff control is used
–the land for disposal of runoff from the holding pond can use about 6 inches of irrigation.

The agent doesn't know the nutrient content of the manure but does know the crop is nonirrigated corn grown for silage. The soil is a sandy loam and, according to Agriculture Handbook 296 (6), the area consists of glaciated plain and belts of moraine hills, beach ridges, and outwash terraces. No conservation or irrigation practices are used. The land is fall plowed.

Using Worksheets 1, 2, 3, 4, and 5, determine the agronomic application rate, the acres of cropland needed for manure application, and the amounts of N, P, and COD lost from the application site.

See page 22 for solution of Sample Problem 2.

Sample Problem 2

WORKSHEET 1. Problem Evaluation

1. What is the manure-management system problem?

A county agent in Rock County, Wisconsin, wants to know if an application rate of 25 tons (wet weight) of dairy manure/acre will supply enough nitrogen to corn, if supplemental nitrogen is needed; how many acres of corn can be fertilized; the application rate on corn land of runoff from the paved lot; and how much N, P, and COD are lost by runoff and deep percolation from the application site.

2. What is known about the current system, i.e., location, climate, livestock or poultry species, animal numbers, etc.?

✓100-head dairy herd housed in a stanchion barn.
✓Barn and paved lot manures are stored in a covered bunker.
✓Lot runoff control is used.
✓Corn is grown for silage, and is not irrigated. Land is fall plowed.
✓Soil is sandy loam and has no salt problem.
✓The area is glaciated plain with moraine hills, beach ridges, outwash terraces (Agriculture Handbook 296).
About 6 inches of irrigation can be used on land for runoff disposal.

3. What answers should the worksheets provide?

✓Agronomic application rates of stored manure and runoff from paved lot.
✓Acres of cropland needed for manure application.
✓Quantity of runoff from the application site.
✓N, P, and COD quantities transported in runoff.

4. With the above information completed, proceed to Worksheet 2, page 23.

Section 3

QUANTITY AND CHARACTERISTICS OF ANIMAL WASTES

The quantity and characteristics of livestock or poultry wastes at the time of land application differ significantly from the initial values for manure excreted by the animal. They are a function of the animal type (table 4), ration fed, physical plant, manure-management system, climate, and time and method of land application. Characteristics include the percent water, total solids (TS), electrical conductivity (EC), COD, and many chemical elements. *Due to the high variation in animal waste characteristics, it is recommended that they be laboratory analyzed prior to land application, if reliable local data are not available.* Laboratory analysis should include TS, EC, N, P, K, calcium (Ca), magnesium (Mg), and sodium (Na).

Waste-Management Systems

The physical plant determines the form or forms (solid, slurry, or liquid) of animal waste. For this manual, "solid" is defined as having TS content greater than 20% (wet-weight basis (w.b.)); "slurry" as having TS content ranging from 8 to 20%; and "liquid" as having TS content less than 8%. Manures having high fiber content cannot be pumped as liquids.

Figure 8 illustrates the subsystems for solid-, slurry-, and liquid-manure management. Systems for handling solids are typically used in outdoor beef cattle, dairy, sheep, and swine units; in poultry units using the dry-litter, and deep-pit, compost methods; and in confined-housing units using bedding or solids separation by mechanical means. Slurry systems are used in dairy, beef, and swine confined-feeding units; in dairy-resting areas with slotted floors or paved areas which are scraped regularly; and in buildings using gutter cleaners with or without bedding. Liquid systems are found in production units that have flush systems, oxidation ditches, oxidation ponds, lagoons, holding ponds, and runoff control for outdoor paved or unpaved feedlots. Table 3 (p. 13) summarizes

TABLE 4.—*Estimated quantities and constituents of livestock and poultry manures produced yearly*[1]

Animal type	Manure quantity			Total solids content	Quantity per animal-year											
	Volume per year	Weight per animal-year			N[2]	P	K	Fe	Zn	Mn	Cu	Ca	Na	Mg	As	COD
	Gal	*Tons, wet*	*Tons, dry*	*%*	*Pounds*											
Dairy	3,614	14.94	1.89	12.7	123	21	98	1.7	0.30	0.41	0.07	72	15	22	0	3,340
Beef	1,614	6.7	.77	1.6	61	18	39	2.0	.20	.20	.03	11.5	4.2	5.7	0	1,510
Swine	548	2.38	.21	9.2	32	7.4	11	.35	2.1	.84	.15	11	1.9	2.9	[3]0	416
Sheep	168	.73	.18	25.0	16	3.7	11	NA[4]	NA	NA	NA	1.0	.78	.78	0	431
Layers [5]	986	3.86	.96	25.0	94	40	40	3.9	.88	.79	.29	170	18	13	0	1,741
Broilers [5]	657	2.62	.65	25.0	78	22	25	12	3.6	.31	.06	91	9.2	9.2	.30	1,183
Turkeys [5]	2,446	10.22	2.55	25.0	304	84	99	45	14	1.2	.25	355	36	36	0	4,599

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[1] Manure production was derived from ASAE Standards (5) Midwest Plan Service (86), and Gilbertson et al (44). The values are commonly used for calculating storage volume and equipment requirements and do not indicate quantities available for land application. Based on average animal weight as follows: Dairy and beef, 1,000 lb; swine, 200 lb; sheep, 100 lb; layers, 4 lb; broilers, 2 lb; and turkeys, 10 lb. These values do not include bedding or other materials such as spilled feed, soil, or water from precipitation. Neither do they reflect the decomposition processes that start as soon as the manure is voided by the animal.

[2] Nitrogen (N), phosphorus (P), potassium (K), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), calcium (Ca), sodium (Na), magnesium (Mg), arsenic (As), and chemical oxygen demand (COD).

[3] May contain up to 0.04 lb per animal per year when As is a feed additive.

[4] Not available.

[5] Per 100 birds.

DAIRY, BEEF, SWINE, SHEEP, POULTRY MANURES

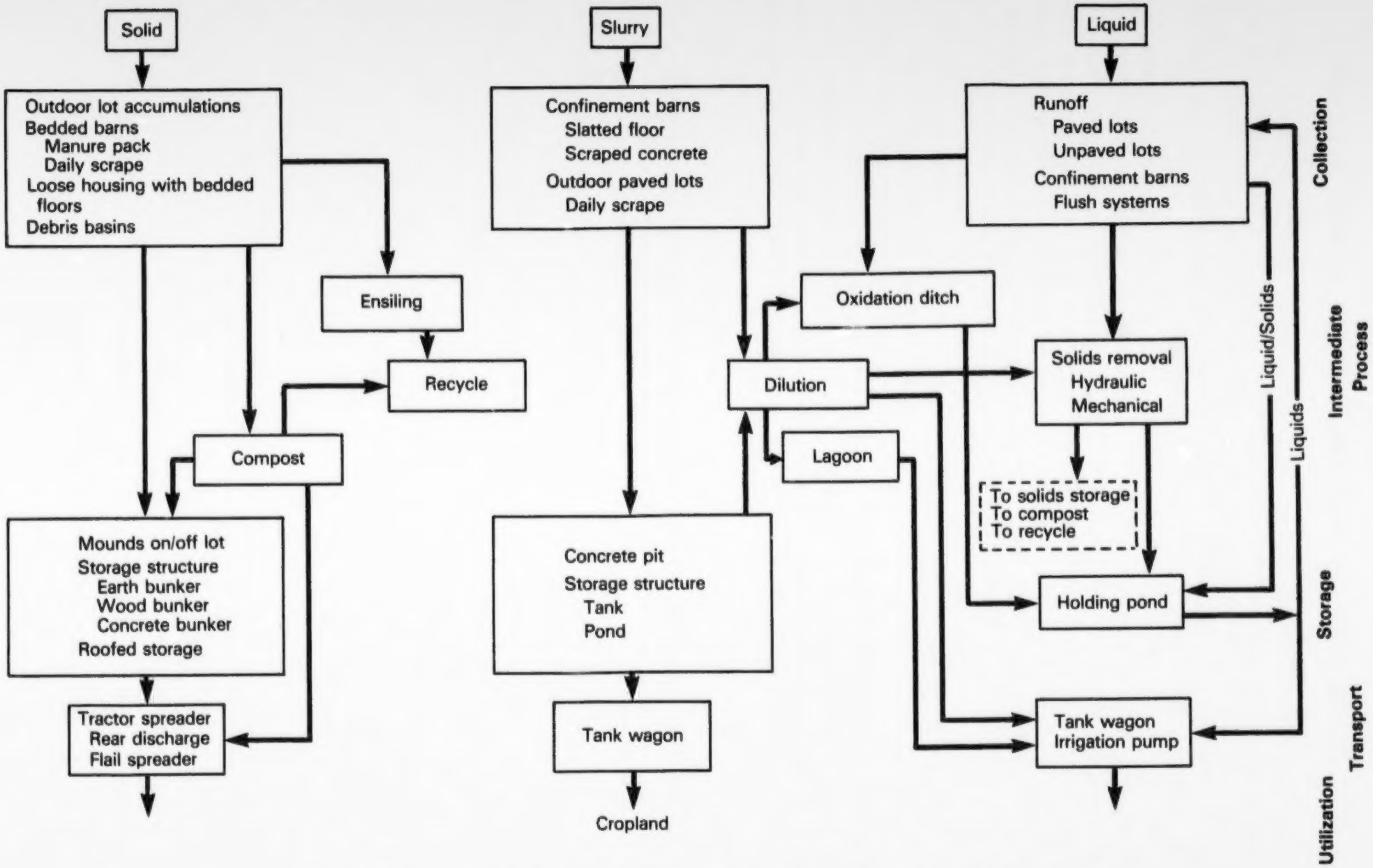

Solid
Slurry
Liquid
Outdoor lot accumulations
Bedded barns
Manure pack
Daily scrape
Loose housing with bedded floors
Debris basins
Confinement barns
Slatted floor
Scraped concrete
Outdoor paved lots
Daily scrape
Runoff
Paved lots
Unpaved lots
Confinement barns
Flush systems
Collection
Ensiling
Recycle
Compost
Oxidation ditch
Dilution
Lagoon
Solids removal
Hydraulic
Mechanical
To solids storage
To compost
To recycle
Liquid/Solids
Liquids
Intermediate Process
Mounds on/off lot
Storage structure
Earth bunker
Wood bunker
Concrete bunker
Roofed storage
Concrete pit
Storage structure
Tank
Pond
Holding pond
Storage
Tractor spreader
Rear discharge
Flail spreader
Tank wagon
Tank wagon
Irrigation pump
Transport
Cropland
Utilization

FIGURE 8.—Components of manure-management systems used in livestock and poultry production.

general categories for manure-management systems for each animal type.

Quantities of material vary because dilution water, wash water, evaporation, or debris (bedding, spilled feed, or soil) may alter the initial volume. The amount of water or bedding needed to change the form of manure to liquid or solid can be calculated from data in the Midwest Plan Service Handbook 18 (86). Total solids available for land application may decrease due to biological degradation of organic matter, seepage losses from storage facilities, and runoff from outdoor lots (1, 28, 34, 35, 49). In this manual, manure quantities are expressed as total solids (either dry- or wet-weight basis) or by volume.

Element Concentration

Concentration of elements in livestock and poultry manures may be expressed in pounds per animal-day or animal-year, pounds per ton (dry or wet basis), pounds per acre-inch, pounds per cubic foot, percent, parts per million, etc. In other references, concentrations may be expressed on a percent wet- (% w.b.) or dry-weight basis (% d.b.).

Element concentrations (% d.b.) vary widely because they are the ratio of element to total solids (E:TS). As TS content decreases, generally E:TS increases. As TS increases, E:TS changes in relation to the composition of the incorporated debris.

Nitrogen content of animal wastes is dependent on the animal type, ration fed, the management system, and the amount of debris mixed in the manure. The N remaining in animal waste after land application varies because N is subject to volatilization, leaching, and runoff losses. Nitrogen is expressed as total N in this manual. When manure decomposes in anaerobic lagoons, holding ponds, and other anaerobic storage structures, ammonia-N (NH_3-N) is formed (69, 117). Nitrite and NO_3-N are formed when manure is oxidized in oxidation ditches or aeration ponds (157).

Phosphorus exists in various forms in livestock and poultry manures. In this manual, phosphorus is expressed as a total P.[3] About 75 to 80% of the P in manures is available to plants (96). Unlike N, P and other elements usually remain in the manures because they are not subject to significant volatilization. Some water-soluble P may be lost by seepage and runoff, however.

Potassium is expressed as total K[4] in this manual. Seventy percent or more of the K voided by livestock and poultry is in urine; therefore, seepage and runoff losses may be high.

Other chemical elements are important even though present in smaller amounts. Ration composition largely determines the concentration of elements in manures. For example, because a high level of calcium (Ca) is fed to poultry (and in some instances to dairy cattle), its concentration in the manure is high. Because low levels of arsenic (As) and copper (Cu) are fed to broilers, small amounts may be present in broiler litter (103).[5]

The chemical characteristics of bedding, soil, or other incorporated materials influence the concentration of elements in the manure. Appendix Tables 1 and 2 show the quantities of collectible manure and the expected ranges in element content. *If reliable local data are not available, laboratory analysis is recommended for all manures before land application.* Care is necessary in order to get representative samples for analysis (112).

Runoff from Paved and Unpaved Feedlots

The United States was divided into eight climatic regions based on temperature and precipitation (fig. 6, p. 11). Climatological patterns for local areas, types of feedlot surfaces, and stocking density (ft^2/animal) affect runoff quantity from feedlots. Since much animal production is concentrated in humid regions, runoff may contain a significant amount of manure.

Climatological factors affecting runoff include precipitation and temperature. Runoff patterns vary widely within and among LRA's (fig. 4, p. 8). Because regions west of the 104th meridian have erratic precipitation patterns, information should be obtained locally.

For runoff estimates, feedlot surfaces were classified as paved and unpaved. For illustrative purposes only, runoff was estimated to be 80% of the annual precipitation for paved feedlots and 30% for unpaved feedlots. Snowmelt may contribute up to 80% of annual runoff in cold-humid regions and up to 30% in cool-humid and cool-arid regions (26, 43, 133).

Table 5 shows the typical area per animal in feed-

---

[3] To convert P to P_2O_5, multiply by 2.29.

[4] To convert K to K_2O, multiply by 1.2.

[5] A mixture of manure and bedding.

TABLE 5.—*Areas per animal used to calculate quantities of runoff for paved and unpaved feedlots*[1]

Livestock type	Climatic area							
	Cold		Cool		Warm		Hot	
	Arid	Humid	Arid	Humid	Arid	Humid	Arid	Humid
	Square feet/animal							
Dairy								
Paved	100	100	75	100	75	100	75	100
Unpaved	1,000	1,000	600	1,000	600	1,000	600	1,000
Beef								
Paved	100	100	60	100	50	60	50	60
Unpaved	450	450	300	450	150	300	150	300
Swine								
Paved	20	20	20	20	15	20	15	20
Unpaved	125	125	100	125	75	100	75	100
Sheep								
Paved	20	20	20	20	15	20	15	20
Unpaved	100	100	75	100	50	100	50	75

[1] Unpaved lot areas for turkeys are 15 ft²/bird for all climatic regions. Pasture areas are 175 ft²/bird for all climatic regions. Paved lots are not recommended for turkeys.

lots, and table 6 shows the maximum average annual precipitation in each LRA. By using the data in these tables, maximum annual feedlot runoff can be calculated as follows: (a) Find the required area (ft^2) per animal in the climatic region in table 5; (b) find the precipitation (in/yr) for the LRA in table 6; and (c) use the constant 0.2 gal/in-ft^2 for unpaved lots or 0.5 gal/in-ft^2 for paved lots and calculate the gallons per animal year for runoff by multiplying the three factors together.

Total solids in the rainfall runoff from beef feedlots have been shown to range from 0.3 to 1.75% (26), depending on the annual precipitation and the moisture deficit. Snowmelt runoff solids content is much higher. The total solids in the runoff from such feedlots can be calculated by assuming a value in this range based on the climate, and multiplying by the gallons of runoff and by 8.34 lb/gal.

Guidelines for estimating runoff and solids transported can be found in Clark et al. (26), Shuyler et al. (119), Gilbertson et al. (40), *or the local data from Soil Conservation Service, university, and extension offices can be obtained for specific animal types in a region.* (Derivation of constants used in this section is shown in the Appendix.)

The solids that settle out of feedlot runoff represent only a small fraction of the animal waste on the lot and are important, basically, because they figure in the management of the debris basin or flow-through solids trap. Settled solids can be applied to land along with manure from lots or pens but are available in much smaller quantities than solid manure. As shown in Sample Problem 2, the estimated quantity of settled solids from runoff is 0.40 ton dry weight. Runoff contains soluble salts, however, and must be carefully managed when used as a fertilizer to avoid damage to the soil or harm to the crops. These topics will be discussed in Section 4.

Except for snowmelt, runoff follows precipitation patterns (43, 119, 130). Figure 9 shows 4-week distribution of annual runoff. Depending on location, snowmelt runoff usually occurs from mid-January through March. In some years, snowmelt runoff may exceed the moisture content of the snow because livestock manures containing moisture have frozen and accumulated on lots.

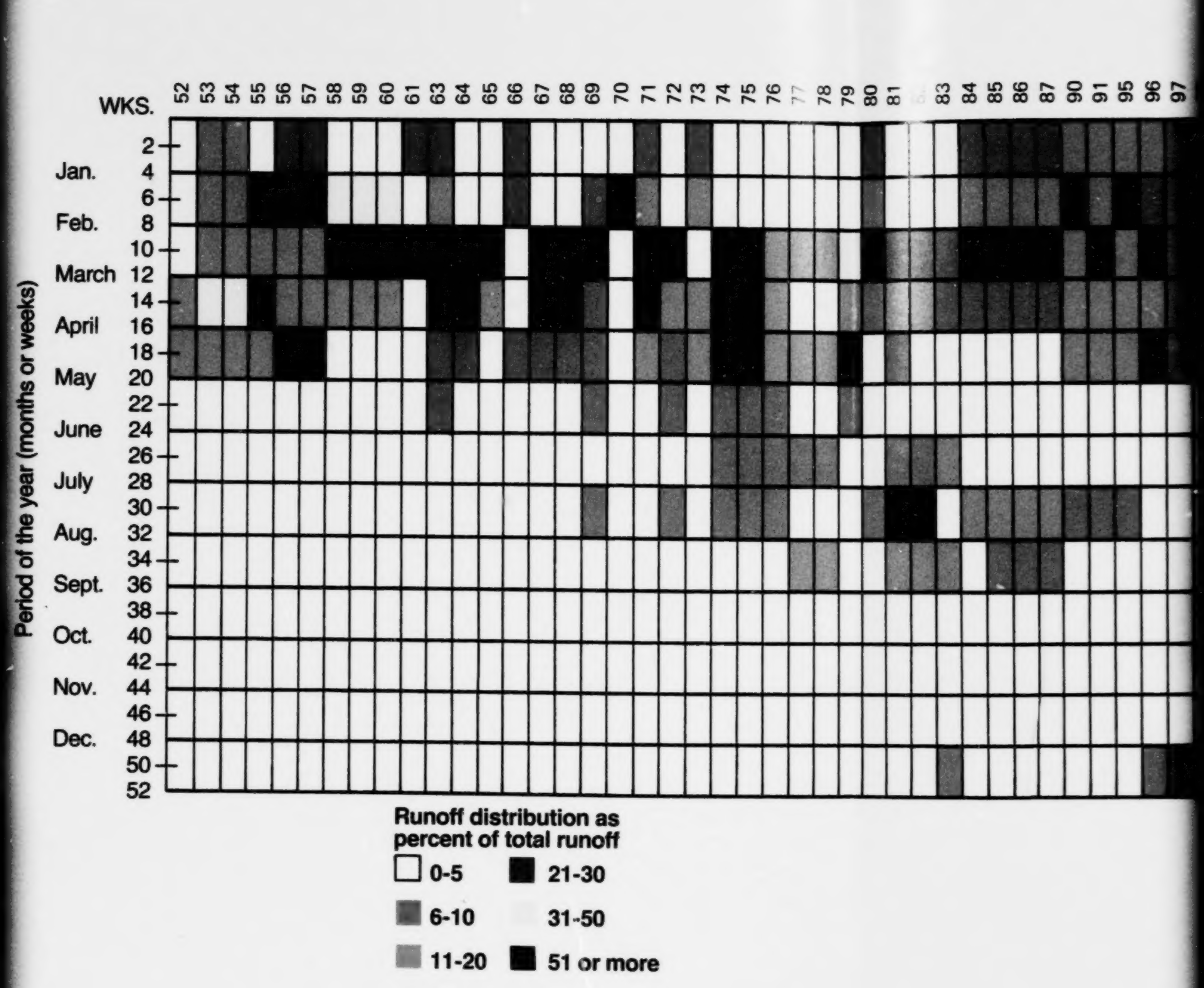
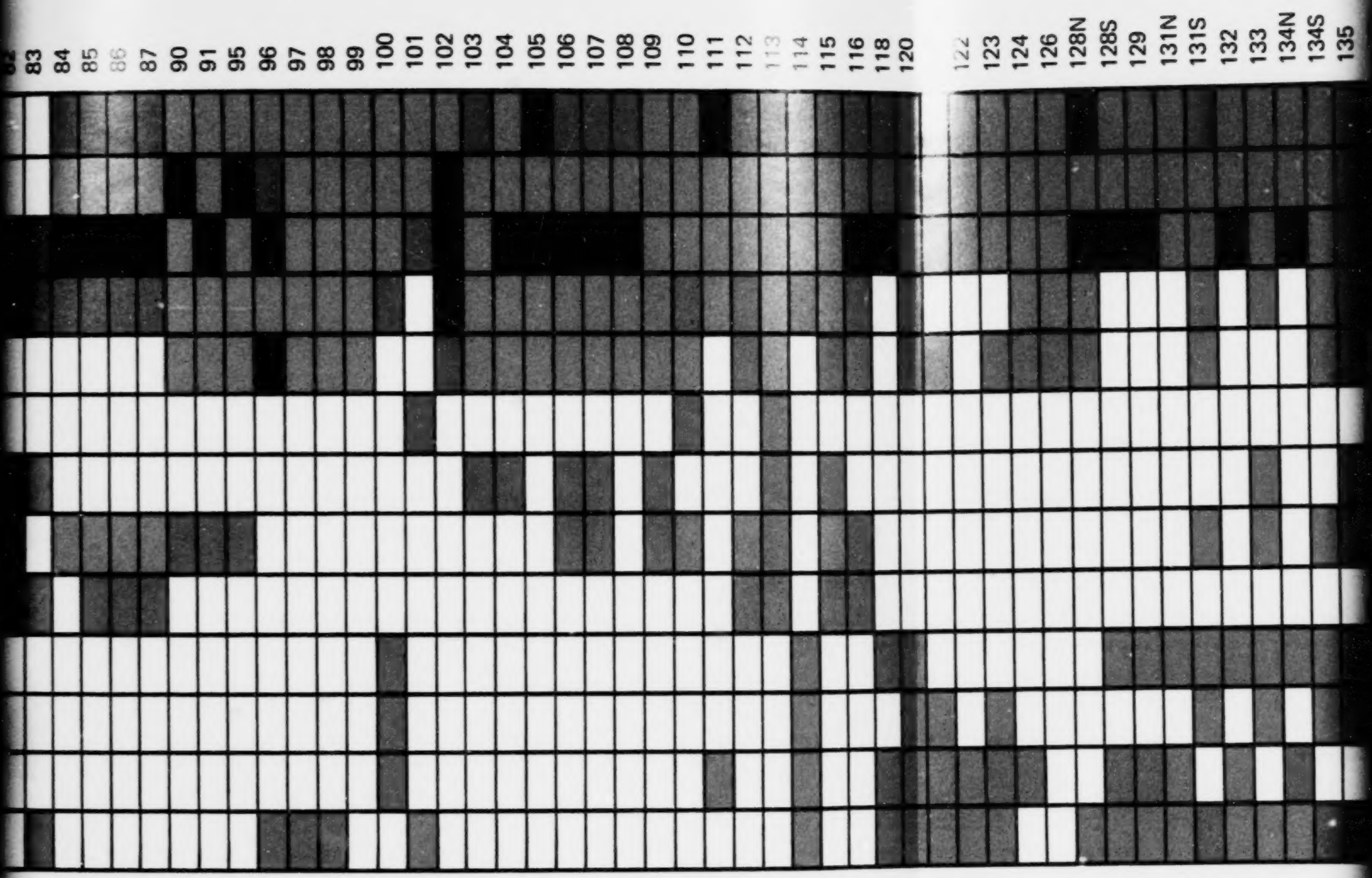
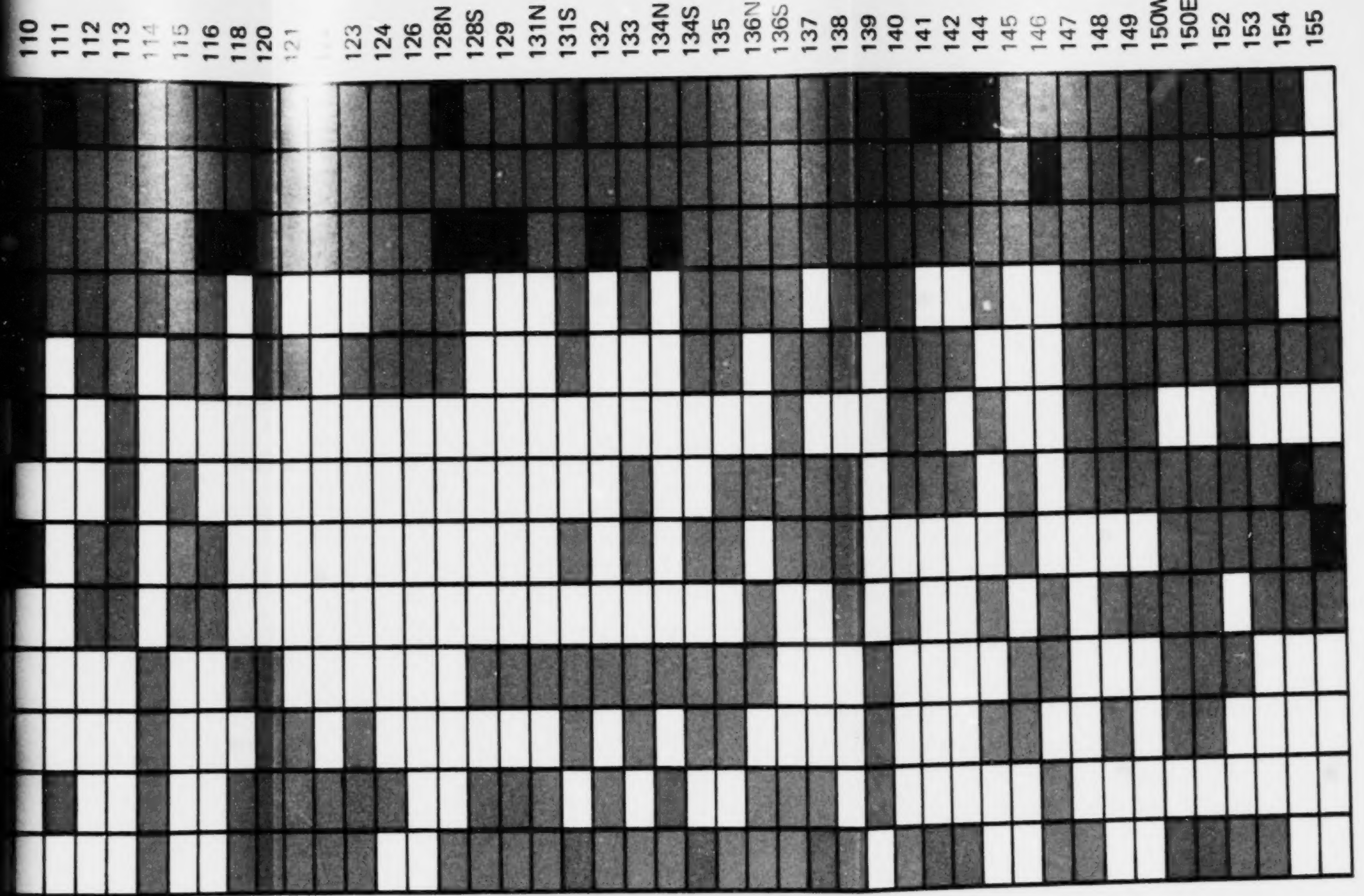


FIGURE 9.—Distribution of annual runoff by four-we



Distribution of annual runoff by four-week and monthly intervals for several Land Resource Areas of the continental United States.

20A



source Areas of the continental United States.

TABLE 6.—*Maximum average annual precipitation for Land Resource Areas of the Continental United States* (7)

Land Resource Area	Maximum average precipitation
	Inches
Land Resource Region A	
1	100
2	60
3	90
4	80
5	70
Land Resource Region B	
6	30
7	14
8	18
9	23
10	20
11	13
12	11
13	20
Land Resource Region C	
14	30
15	30
16	15
17	25
18	40
19	25
20	40
Land Resource Region D	
21	20
22	60
23	14
24	12
25	16
26	15
27	12
28	20
29	12
30	10
31	4
32	14
33	16
34	12
35	16
36	13
37	10
38	14
39	35
40	10
41	20
42	16
Land Resource Region E	
43	50
44	16
45	40
46	20
47	20
48	30
49	20
50	8
51	20
Land Resource Region F	
52	15
53	18
54	19
55	20
56	22
57	24
Land Resource Region G	
58	16
59	16
60	16
61	18
62	24
63	20
64	18
65	23
66	24
67	36
68	15
69	15
70	16
Land Resource Region H	
71	25
72	21
73	25
74	28
75	30
76	35
77	23
78	30
79	28
80	35
Land Resource Region I	
81	35
82	40
83	35
Land Resource Region J	
84	35
85	35
86	35
87	42
Land Resource Region K	
88	25
89	25
90	30
91	32
92	30
93	30
94	30
Land Resource Region L	
95	32
96	30
97	36
98	36
99	36
100	35
101	45
Land Resource Region M	
102	30
103	33
104	33
105	35
106	36
107	36
108	35
109	40
110	35
111	40
112	45
113	40
114	45
115	45
Land Resource Region N	
116	40
117	52
118	50
119	45
120	40
121	45
122	54
123	50
124	45
125	50
126	45
127	60
128	45
129	54
130	50
Land Resource Region O	
131	50
132	50
Land Resource Region P	
133	60
134	53
135	60
136	55
137	50
138	55
Land Resource Region R	
139	40
140	40
141	40
142	35
143	50
144	45
145	45
146	40
Land Resource Region S	
147	45
148	45
149	50
Land Resource Region T	
150	40
151	65
152	64
153	50
Land Resource Region U	
154	57
155	60
156	64

Table 7 shows quantities and characteristics of livestock and poultry manures for illustrative use in the sample problems. Quantities are listed for dry manure available, percent total solids, and elemental composition. More extensive data on manures, showing the effects of management and pretreatment, are given in Appendix tables 1 and 2. *Values for quantities and characteristics of animal wastes listed in table 7 and in Appendix tables 1 and 2 are intended for illustrative use only.* Animal wastes should be analyzed and quantities estimated prior to land application if reliable local data are not available. With local data, planners could estimate both the quantity of animal wastes and the concentrations of elements in them for different physical plants.

Manure from horses is of local interest, so data are not given beyond the following: 9.4 lb of manure, dry weight, per day at 20.6% total solids; and 2.9, 0.49, and 1.8% N, P, and K, respectively, for a 1,000-lb animal. Bedding could amount to 33 lb of straw per day per animal. Other details on management are found in the publication by Sojka (121).

Worksheets 2, 3, 4, and 5 on pages 23, 41, 80, and 84 illustrate some calculations of Sample Problem 2.

Worksheet 2 Instructions

Worksheet 2 may be used to estimate quantities of manure available for land application from specific livestock or poultry operations. Refer to Sample Problem 2, Section 2, page 15.

The following steps give a systematic procedure and correspond to the numbers on the worksheet:

1. Use figure 4, page 8, to determine the Land Resource Area (LRA).
2. Use figure 6, page 11, to determine the climatic region.
3. Enter the type of livestock or poultry.

TABLE 7.—*Some estimated quantities and characteristics of livestock and poultry manures at the time available for land application*

Source of manure	Dry manure available	Total solids	Element							
			N	N range	P	K	Ca	Mg	Na	Salt[2]
	Tons per year	%								
Dairy, stored	1.9	18	[3] 2.0	1.5 – 3.9	0.6	2.4	2.3	0.7	0.4	11.6
Dairy, removed daily	2.4	13	3.2		.6	2.4	2.3	.6	.3	11.2
Dairy runoff	—	0.1	[4]0.015	[4].001–0.86	.005	.085	.016	.011	.053	[6] 4.7
Beef	1.0	52	2.1	.6 – 4.9	.8	2.3	2.0	.7	.7	11.4
Beef runoff	—	0.1	[4]0.1	[4].001– 0.86	.01	.01	.02	.01	.06	[6] 2.9
Swine	.15	18	2.8	2.0 – 7.5	.6	1.5	2.3	2.4	.6	13.6
Swine lagoon	.10	1	[4]0.024	[4].01 – 0.15	.005	.025	.005	.006	.06	[6] 2.7
Sheep	.09	28	4.0	.9 – 5.4	.6	2.9	1.7	.5	.7	11.6
Hen [5]	1.0	45	5.0	3.0 –11	1.8	1.4	3.4	.5	.7	12.0
Hen litter [5]	1.2	75	2.8	1.2 – 5	1.9	1.9	3.5	.5	.7	13.2
Broiler litter [5]	.8	75	3.9	1.21 – 5.0	1.5	2.0	1.9	.5	.7	10.2

[1] Based on average animal weight as follows: Dairy and beef, 1,000 lb; swine, 200 lb; sheep, 100 lb; layers, 4 lb; broilers, 2 lb. These values reflect management and decomposition effects. More extensive data on manures are given in Appendix tables 1 and 2.

[2] Sum of K+Ca+Mg+Na percentages times 2 is a reasonable estimate of the amount of salt.

[3] Percent composition on dry-weight basis for solid manures.

[4] Percent of wet weight of runoff or lagoon liquids. Swine-lagoon water is analogous to dairy and beef runoff.

[5] Amount per 100 birds.

[6] Electrical conductivity (EC) in mmhos/cm. Assume EC of 1 mmho/cm = 0.064% salt or 640 ppm (140).

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SAMPLE PROBLEM 2

Worksheet 1. Determining Quantities of Livestock or Poultry Manures Available for Land Application

1. Location (LRA, Figure 4, page 6) 95
2. Climate (Figure 6, page 11) .... ✓ cold, ___ cool, ___ warm, ___ hot, ✓ humid, ___ arid,
3. Animal type .... Dairy
4. Number of animals (one-time capacity or inventory number) 100
5. Management system (Problem description) .... Stanchion barn; paved lot; covered bunker
6. Check manure source and form and fill in the blanks below using local data for characteristics.

Manure Source and Form				Wet Quantity			Dry Weight		
Source[1] (Table 7, page 22) (1)	Form Solid (2)	Form Slurry (3)	Form Liquid (4)	Wet weight or gal/animal/year[2] (5)	x Animal number (6)	= Annual wet quantity (7)	Dry weight/animal/year (8)	x Animal number (9)	= Annual dry weight[6] (10)
Barn									
Pack									
Pit									
Floor									
Paved lot									
Unpaved lot									
Runoff (Tables 5 and 6, pages 20 & 21; text, page 20)									
Effluent[4]									
Settled Solids[4]							(	)[4]	
Stored Manure	✓			10.56	100	1,056	1.90	100	190
Holding pond (agitated)[3]									
Effluent[4]			✓	1600	100	160,000	.00667	100	0.67
Settled Solids[4]							(0.67	0.6)[4]	0.40
Anaerobic lagoon (agitated)[3]									
Effluent[4]									
Settled Solids[4]							(	)[4]	
Aerobic lagoon (agitated)[3]									
Effluent[4]									
Settled Solids[4]							(	)[4]	
Oxidation ditch									
Oxidation ditch overflow holding pond (agitated)[3]									
Effluent[4]									
Settled Solids[4]							(	)[4]	
Other									
....									
....									

---

[1] Include all sources and forms of manures for a particular system.

[2] Liquids are expressed in gallons per animal per year, to convert gallons to acre-inches, divide by 27,150 gal/acre-in; slurry and solids are expressed in tons/animal/year.

[3] If holding ponds or lagoons are not agitated when pumped out, or a debris basin is used to separate solids, enter wet quantity under effluent.

[4] If ponds, lagoons, etc., are not agitated, estimate dry weight effluent and settled solids as follows: Settled solids dry weight = total runoff solids times 0.6. If available, use reliable local estimates of the fraction of total runoff solids that can be expected to settle out.

4. Enter the maximum one-time animal capacity of the physical plant.
5. Enter the manure-management system resembling that used in the animal-production operation.
6. Check the appropriate manure sources and forms on the worksheet blanks. Complete the calculations for wet and dry weights as follows:

   a. Use tables 5, 6, and 7 (pp. 20, 21, and 22) to determine the wet and dry weights or gallons of waste available per animal per year. The form would be "liquid" if the holding pond is agitated before effluent is removed. The forms are "liquid" and "solid" if the holding pond is not agitated and solids were allowed to remain in the pond when effluent is removed. Locate the area required per animal (ft^2) in the climatic region in table 5. Find the maximum average annual precipitation (in/yr) for the LRA in table 6. Use the constant 0.5 gal/in-ft^2 for runoff from paved lots and 0.2 gal/in-ft^2 for runoff from unpaved lots. Multiply these three factors together and insert the answer in Column 5. Calculate the total dry solids in runoff by using the amount of runoff (gal/animal-yr) times the percent solids in the runoff (estimated for the climatic region) divided by 100, times 8.34 lb/gal times $\frac{1 \text{ ton}}{2{,}000 \text{ lb}}$, i.e., 1,600 gal/animal-year x 0.1%/100 x 8.34 lb/gal x 1 ton/2,000 lbs = 0.0067 ton/animal-yr for Sample Problem 2. Place the answer in column 8. Table 7 gives the total dry solids weight and the percent water. Enter the appropriate weight and number of animals in the blanks of the worksheet. Divide the dry weight by 1/100 of the percent dry matter to determine the wet quantities for each animal waste, i.e., 1.90 tons $\div \frac{18}{100} =$ 10.56 tons/animal-year for Sample Problem 2. Multiply each weight by the animal number to get the total wet and dry quantities. The settled solids dry weight can be estimated by multiplying the total solids in the runoff by 0.6. The quantities for each source of manure will be carried through to Worksheet 3 for calculations of application rates.

Section 4

LAND-APPLICATION PLANNING

Methods of applying animal wastes influence their impact on the environment. Applied to soils in proper amounts, animal wastes improve soil fertility and crop yields. Carelessly handled, they impair soil productivity, degrade the quality of surface and ground water, and cause nuisance complaints by neighbors. A complete plan for animal waste use consists of site selection, time and method of land application, effects of wastes on soil properties and plants, and application rates.

Site Selection

Potential land-application sites must be evaluated for distance from the feedlot or animal production unit, perimeter land use, land-use plans, climate, topography, geology, prevailing wind direction, and cropping systems (86, 87, 119). Table 8 summarizes site evaluation criteria. A map may be prepared to help visualize factors affecting the land-application site and its compatibility with the local area (149, 150, 151). The map should show distances to neighboring farms, streams, lakes, cities, and/or other facilities within a 3- to 5-mile radius. Figure 10 is an example of such a map.

Climate evaluation requires information on seasonal characteristics, precipitation, temperature, and wind. Local climatic information may be obtained from the Soil Conservation Service or the U.S. Department of Commerce (147).

Evaluation of topographic and geologic factors re-

TABLE 8.—*Evaluation checklist for a livestock or poultry manure application site*

General Information

A. ________Distance of land-application site from manure source
B. ________Distance of land-application site from waterways, urban areas, or other residences.
C. ________Proposed land use
    1. Agricultural
    2. Recreational
    3. Urban development
D. ________Zoning requirements
E. ________Expansion potential (additional land available)

Environmental Interactions

A. Climate
    1. ________Seasonal characteristics
    2. ________Precipitation
    3. ________Temperature
    4. ________Prevailing wind direction
    5. ________Evapotranspiration
B. Topographic and geologic features
    1. ________Land slope; slope length
    2. ________Erosion
    3. ________Flood potential
    4. ________Percolation rates
    5. ________Soil profile characteristics
    6. ________Ground water depth and availability
    7. ________Well locations

Land-Use History

A. ________Crop rotations, pastureland, forest, etc.
B. ________Conservation practices
C. ________Irrigation potential

quires information on land slope, erosion potential, and soil type (20). The U.S. Department of Agriculture (USDA), Soil Conservation Service (SCS) may be consulted for advice or for their guide, Agricultural Waste Management Field Manual (142). Information in the guide may be used to determine runoff, soil transport, and ground water pollution potential. Additional information is available in the manuals, Control of Water Pollution from Cropland, Volumes I and II (126, 127). General information on climate, topography, geology, and cropping systems for LRA's is available in Agriculture Handbook No. 296 (7).

Time and Method of Land Application

Proper and timely application of animal wastes is important in minimizing nutrient losses and pollution potential (56, 58, 84, 105, 138, 165). Time and method of application depend on climate, cropping system, management system, and source and form of animal waste (table 9). Equipment and labor availability also influence time and method of land application.

Caution should be used when applying manure to steep, frozen, and/or snow-covered ground. When applied to crops, such as on grass or alfalfa, under conditions leading to maximum spring runoff, snowmelt runoff can transport large amounts of the organic materials and other potential pollutants from the land (29, 130, 169). Although extended periods of above-freezing temperatures may thaw the surface layer of soil, a frozen sublayer may prohibit water infiltration.

Local precipitation records should be evaluated to avoid spreading wastes when runoff or leaching potential is high. To spread slurry or solids, soils must be dry enough to support farm machinery and avoid soil compaction. Even though wet ground does not interfere with sprinkler application, extra water could result in greater nutrient leaching and runoff losses. In some regions, at least 5 to 10% of the N is lost

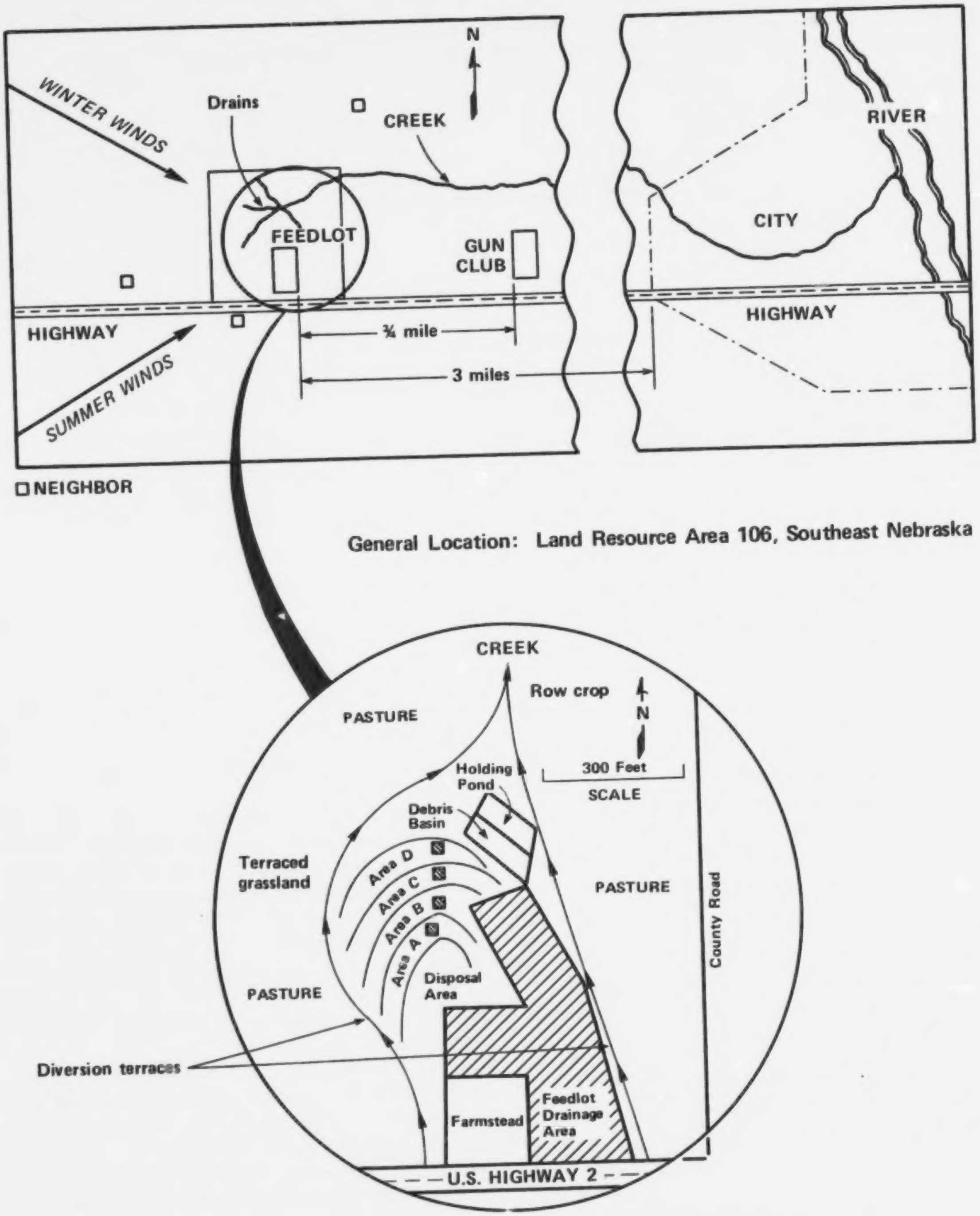
WINTER WINDS
Drains
CREEK
N
FEEDLOT
GUN CLUB
HIGHWAY
¾ mile
3 miles
SUMMER WINDS
NEIGHBOR
RIVER
CITY
HIGHWAY
General Location: Land Resource Area 106, Southeast Nebraska
CREEK
Row crop
N
PASTURE
Holding Pond
300 Feet
SCALE
Debris Basin
Terraced grassland
Area D
Area C
Area B
Area A
PASTURE
Disposal Area
PASTURE
County Road
Diversion terraces
Farmstead
Feedlot Drainage Area
U.S. HIGHWAY 2

FIGURE 10.—Illustrative map for a local area and a site receiving livestock or poultry manure.

TABLE 9.—*Most probable months to apply livestock and poultry manures to land in different climatic regions of the continental United States*

Manure form	Climatic regions of the United States [1]							
	Cold		Cool		Warm		Hot	
	Humid	Arid	Humid	Arid	Humid	Arid	Humid	Arid
SOLID	May June Aug. Sept.	May June Sept.	April May Oct. Nov.	April May Oct. Nov.	March April Aug. Sept. Oct.	Year Around	Year Around	Year Around
SLURRY	May June July Aug. Sept.	April May June July Aug. Sept. Oct.	March through Dec.	April May Aug. Sept. Oct. Nov.	Year Around	Year Around	Year Around	Year Around
LIQUID (RUNOFF)	May June July Aug. Sept.	May June Sept.	March through Dec.	March through Dec.	Year Around	Year Around	Year Aound	Year Around

[1] See figure 6 for location of climatic regions.

through leaching if animal wastes are applied in the fall rather than near planting time (130).

Row-crop, no-till systems, and small grains can receive animal wastes before planting or after harvest. Slurries or liquids may be applied before land preparation, after harvest, or through pipeline irrigation systems as needed during crop growth. On irrigated land, time should be allowed for salt dispersion and nitrification so ammonium concentrations are within crop tolerance levels at planting time (77, 84, 123). Small grains or suitable grasses grown during winter reduce nutrient leaching and enhance nutrient recovery. In areas of high rainfall, leaching may be excessive if animal wastes are applied far in advance of planting. Coarse-textured soils, because of high water permeability or intake rate, accept high liquid application rates without runoff. Since most coarse-textured soils have a very low ability to hold plant nutrients, animal wastes should be applied at low rates to those soils throughout the growing season to reduce N leaching.

Grasses can receive solid, slurry, or liquid wastes at any time except during germination and seedling stages. The best time is usually after a period of grazing by livestock or following each hay harvest. No more than 1.5 inches or liquid or slurry (about 5% solids) should be applied to pastures within a 30-day period (84). The percentages of TS and N in the animal waste control the amount that can be applied. Grasses tolerate heavier applications of liquids than broadleaf plants, but cattle may not eat grass coated with large quantities of their own wastes. In warm climates, all-year pasture systems may be used to remove maximum amounts of nutrients from the soil and limit leaching losses.

The method of application depends on whether the manure is in solid, slurry, or liquid form. Solids are usually spread with rear-discharge spreaders, uniformly and in a single operation. Slurries may be hauled directly to the field with tank wagons or diluted with water and pumped to the field through pipeline irrigation equipment. Dilution of slurry with water to form liquid is becoming more popular as irrigated acres increase, but dilution increases the volume that must be handled (86). For example, increasing the water content of a manure from 80 to

95% quadruples the volume. Liquids can be spread by flood, furrow, or sprinkler systems. Sprinkler application gives the highest uniformity. Sprinkling should be avoided on days with high humidity or winds if odors are carried to populated areas.

Uniform spreading of slurries and liquids prevents concentrations of NH_4-N and inorganic salts that can reduce crop germination and yields. Animal wastes should be incorporated as soon as possible to avoid loss of N by volatilization (84, 86, 116). Prompt soil incorporation also prevents rain or melting snow from washing pollutants into streams.

Effect of Animal Wastes on Soils and Plants

Land application of livestock or poultry wastes may alter a number of soil properties such as soil tilth, water infiltration rate, water-holding capacity, oxygen content, and soil fertility. Factors affecting leaching, denitrification, and runoff losses are rainfall, topography, soil texture, and amount of manure applied.

Hydrologic characteristics of the land are important since they affect the rate, volume, and flow path of water. Musgrave (91) classified soils into four hydrologic soil groups:

Group A (low-runoff potential)—Soils having high infiltration rates even when thoroughly wetted. This group includes very permeable, deep sands and deep, aggregated silts of loessial origin. These soils have little clay and colloid, and the silts have enough organic matter to provide good aggregation.

Group B (low- to moderate-runoff potential)—Soils having moderate infiltration rates when thoroughly wetted. This group includes sandy soils and silt loams of moderate depth and above-average infiltration. The minimum infiltration rate ranges from about 0.15 to 0.30 in/hr.

Group C (moderate- to high-runoff potential)—Soils having low infiltration rates when thoroughly wetted. This group consists chiefly of soils with a layer that impedes the downward movement of water. This group includes shallow soils in all textural classes. The minimum infiltration rates are generally between 0.05 and 0.15 in/hr.

Group D (high-runoff potential)—Soils having very low infiltration rates when thoroughly wetted. This group includes soils consisting of clays with high swelling potential, soils with permanent high water tables, soils with a claypan at or near the surface, and shallow soils over nearly impervious material.

Soil tilth refers to the physical condition of the soil and is used to describe factors such as aggregate formation and stability, moisture content, degree of aeration, infiltration rate, drainage, and water-holding capacity. These factors all influence the ease of tillage, fitness of a seedbed, and impedance to seedling emergence and root penetration. Livestock and poultry wastes improve soil tilth and are compatible with most soils (78, 79, 114, 115, 120, 170).

The infiltration rate is the rate at which water enters the soil. It is dependent on the proportion of coarser pores in the soil surface, the stability of surface aggregates, the soil water content, and the amount of surface cover at the time of rainfall or irrigation (54). Infiltration rate, particularly in fine-textured soils, is increased by incorporation of animal wastes. Although slurry applied to the soil surface may initially seal the soil and decrease infiltration, time or tillage will restore the infiltration capacity. More detail on infiltration can be found in the SCS Agricultural Waste Management Field Manual (142).

By increasing water-holding capacity, animal wastes stimulate plant growth. For example, if the crop is Coastal bermudagrass on coarse, sandy soil, heavy application of wastes usually results in leaching only in the dormant season. Even under row crops on sandy soils, wastes reduce leaching and increase crop yields by helping plants use water and nutrients (32, 71, 159).

A soil oxygen supply is necessary for decomposition of organic wastes and mineralization of their organic nitrogen by soil micro-organisms. However, the high biochemical oxygen demand (BOD) of excessive wastes or the time and method of application may lead to anaerobic soil conditions, causing NH_3-N and NO_2-N toxicity to plants (80). If wastes are applied at agronomic rates, soil oxygen deficiencies and undesirable end products of decomposition are minimal (100).

Soil fertility is a function of the nutrients contained in soil and their availability to plants (3, 33). Nutrient amounts needed by crops vary with species, as indicated by the elements found in harvested crops shown in table 10. Because some plants are more vigorous than others in absorbing nutrients, soils deficient in certain elements for one crop may have enough available for another. Each fertilizer element contributes to the well-being of the plant. However, deficiencies or excess of certain elements in the soil affect crop yields (94). The quantity of

TABLE 10—*Selected elemental content found in common crops on an area basis*[1]

Crop	Yield per acre[2]		Element per acre					
			N	P	K	Ca	Mg	Na
	Tons	Bushels	*Pounds*					
Barley (Grain)	0.96	40	35.00	7	8	1.00	2.00	0.38
Barley (Straw)	1.00		15.00	2	25	8.00	2.00	2.80
Corn (Grain)	4.20	150	135.00	23	33	16.00	20.00	0.00
Corn (Stover)	4.50		100.00	16	120	28.00	17.00	0.00
Oats (Grain)	1.28	80	50.00	9	12	2.00	3.00	1.79
Oats (Straw)	2.00		25.00	7	66	8.00	8.00	14.80
Rice (Rough)	1.80	80	50.00	9	8	3.00	4.00	0.00
Rice (Straw)	2.50		30.00	4	58	9.00	5.00	0.00
Rye (Grain)	0.84	30	35.00	4	8	2.00	3.00	0.34
Rye (Straw)	1.50		15.00	3	21	8.00	2.00	3.90
Sorghum (Grain)	1.68	60	50.00	11	12	4.00	5.00	1.68
Sorghum (Stover)	3.00		65.00	9	79	29.00	18.00	0.00
Wheat (Grain)	1.20	40	50.00	11	12	1.00	6.00	2.40
Wheat (Straw)	1.50		20.00	2	29	6.00	3.00	4.20
HAY								
Alfalfa	4.00		180.00	18	149	112.00	71.00	0.00
Bluegrass	2.00		60.00	9	50	16.00	7.00	0.00
Coastal Bermuda	8.00		185.00	31	224	59.00	24.00	0.00
Cowpea	2.00		120.00	11	66	55.00	15.00	10.80
Peanut	2.25		105.00	11	79	45.00	17.00	0.00
Red Clover	2.50		100.00	11	83	69.00	17.00	7.50
Soybean	2.00		90.00	9	42	40.00	18.00	0.00
Timothy	2.50		60.00	11	79	18.00	6.00	0.00
FRUITS AND VEGETABLES								
Apples	11.75		30.00	4	37	8.00	5.00	0.00
Beans (Dry)	0.90		75.00	11	21	2.00	2.00	0.00
Cabbage	20.00		130.00	15	108	20.00	8.00	0.00
Onions	7.50		45.00	9	33	11.00	2.00	0.00
Oranges	28.00		85.00	13	116	33.00	12.00	0.00
Peaches	14.40		35.00	9	54	4.00	8.00	0.00
Potatoes (Tubers)	12.00		80.00	13	125	3.00	6.00	0.00
Spinach	5.00		50.00	7	25	12.00	5.00	0.00
Sweet Potatoes	8.25		45.00	7	62	4.00	9.00	0.00
Tomatoes (Fruit)	20.00		120.00	18	133	7.00	11.00	0.00
Turnips (Roots)	10.00		45.00	9	75	12.00	6.00	0.00
OTHER CROPS								
Cotton (Seed & Lint)	0.75		40.00	9	12	2.00	4.00	0.00
Cotton	1.00		35.00	4	29	28.00	8.00	0.00
Peanuts (Nuts)	1.25		90.00	4	12	1.00	3.00	0.00
Soybeans (Grain)	1.20		150.00	15	46	7.00	7.00	0.00
Sugar Beets	15.00		60.00	9	42	33.00	24.00	0.00
Sugarcane	30.00		96.00	24	224	28.00	24.00	0.00
Tobacco (Leaves)	1.00		75.00	7	100	75.00	18.00	0.00
Tobacco (Stalks)	0		35.00	7	42	0	0	0

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[1] Based on values from *Our Land and its Care*, National Fertilizer Institute, 4th ed., 1962, pp. 24–25 (94). The values may vary with soil type, season, soil fertility, and should be adjusted proportionally to crop yields. *These values do not represent crop requirements*, because additional nutrients are needed for roots or tops not harvested and certain soil factors influence the efficiency with which nutrients are absorbed.

[2] Grain, fruit, and vegetable yields were computed at 48 lb/bu for barley, 56 lb/bu for corn, 32 lb/bu for oats, 45 lb/bu for rice, 56 lb/bu for sorghum, 60 lb/bu for wheat, 47 lb/bu for apples, 60 lb/bu for beans, 48 lb/bu for peaches, 60 lb/bu for potatoes, 55 lb/bu for sweet potatoes, 56 lb/bu for rye, and 60 lb/bu for soybeans.

nutrients in a crop is always less than the amount required in the soil (crop requirement) to support the crop because several plant and soil factors combine to reduce the efficiency with which nutrients are absorbed and utilized by the plants.

Livestock and poultry wastes supply many of the elements essential to plant growth (12, 24, 37, 128). When adequate N is supplied by animal wastes, P and K are usually adequate for crop production as well. Although the P supplied often exceeds crop requirements, it does not approach toxic levels and has not been a problem (31, 96, 97). Excess Na and K may contribute to salt accumulation, soil structure deterioration, and, in some cases, yield reduction (46, 60).

Manures increase the levels of available Zn and Fe in the soil and subsequently increase levels in plant tissues (36, 50, 88, 155). Copper levels in plants and soils where manures have been applied either remain stable or increase slightly (36, 47, 99, 155). Studies have shown Mn levels can either increase (36, 155) or decrease (6, 49, 50, 99).

Crop yields may be adversely affected when elements essential for plant growth reach excessive levels in soils (15, 76, 111, 155). Since As compounds are not essential for plants and are relatively insoluble and resist leaching, they tend to accumulate in soils. Broiler litter and some swine manure contain traces of As, but studies have shown that plant growth on land loaded with broiler litter is not retarded by As accumulation.

Nutrient imbalances in soils in some areas have been associated with metabolic disorders in animals consuming forages grown on the soils. The incidence of grass tetany, a disorder characterized by low Mg levels in the blood, has increased in cattle on pastures where large quantities of poultry manures have been applied. High levels of NO_3-N in the soil stimulate plant uptake of K, but not that of Ca and Mg. The ratio of $K/(Ca+Mg)$ is increased, and this may cause Mg deficiency in pregnant or lactating cows. Wilkinson et al. (161) found that application of a magnesium oxide (MgO) and bentonite clay-slurry to the foliage of plants decreased the incidence of grass tetany.

Other metabolic disorders in animals have been associated with excessive N accumulation in soils treated with livestock and poultry manures. High accumulations of NO_3-N in forage crops may approach toxic levels (110, 155, 162). High N fertilization of tall fescue, regardless of N source, has been associated with increased incidence of fat necrosis, which is the occurrence of hard, fat lesions predominantly within the abdominal cavity of cattle (129, 163).

Even when livestock and poultry manures are applied to land at agronomic rates, *periodic soil tests are recommended*. Tests for nitrate, ammonia, and salt in addition to standard soil tests will determine whether N is being used efficiently, whether salinity problems exist, whether certain elements are present at toxic levels, or whether increased concentrations of one element (such as P) have reduced the availability of another (Zn) to plants.

Planning Application Rates

Available N and salt limitations are the major determining factors in controlling land application rates of livestock and poultry manures. Since N is both the most used element for production of optimum yields and the most mobile element (thus creating potential for surface and ground water pollution), it is the most logical component on which to base application rates. In some irrigated areas, however, salt buildup in the soil may limit application rates. Even in nonirrigated areas, manure rates must be reduced if salt accumulations result in reduced yields. *Because of these factors, the most useful short-range guidelines for determining land-application rates of livestock and poultry manures are N and salt contents.*

Manures having a low N content and considerable moisture would require application of high tonnages to satisfy crop needs for N to obtain high yields. Therefore, it is recommended that approximately half the N requirement be met with manure and the other half from commercial fertilizer. This practice will help conserve the P and K by applying them at a more realistic rate. Potential salt problems will be reduced or eliminated.

Nitrogen

The amount of N needed at a specific site depends on crop requirements, N available in the soil, and N losses through volatilization, leaching, denitrification, and runoff.

Some crops require greater amounts of N in the soil than others to produce optimum yields. Care should be taken, however, to avoid basing N application rates solely on desired yields. Although N is the basis for maximizing yields, they will not increase beyond a certain point regardless of the amount of N applied (21). Some crop yields and/or quality may be reduced by excessive quantities of N (48, 76, 111, 155).

The amount of N available in the soil before application of manure may be estimated from soil tests. The percentage of the total N *readily available* to plants varies among soils, but only a small percentage is available to crops during one season. The range is from near zero to as high as 10% per year, but, in most soils, the range of available N is from 1 to 6% of the total N in soils (122). A good discussion of the role of soil testing in determining N needs is available in the book on corn production edited by Pierre et al. (59). Soil testing for available N generally is not done east of the Mississippi River. Instead, empirical procedures are used to estimate the N-supplying ability of the soil.

The amount of N lost by volatilization is affected by the method of manure application. Table 11 shows ammonia losses through volatilization within 4 days after application by various methods. The immediate incorporation of manure into the soil significantly reduces N loss.

Because manure has a high moisture-holding capacity and the N is released slowly, it is assumed that potential leaching losses will be decreased when the manure is applied at the beginning of the growing season. Denitrification losses usually occur in oxygen-depleted soils. Because this condition is common only in Group D soils (heavy clay), denitrification is not a major problem in most agricultural areas. Denitrification varies with the type of management, precipitation (or irrigation), and amount of organic matter in soil of a given texture (83). In this manual, the denitrification coefficients are assumed to be 0, 0.10, 0.20, and 0.35 for hydrologic soil types A (sandy), B (sandy, silty loam), C (shallow, relatively heavy), and D (heavy clay), respectively. In other words, 35% of the N incorporated in type D soils denitrifies and is lost to the air as N_2. Prolonged soil oxygen depletion may reduce crop yields more than denitrification would. When manure is incorporated, negligible fertilizer will be lost from the manure in runoff.

The values for volatilization losses (table 11, p. 31) were multiplied by the coefficients for denitrification losses. These values produced the multiplication factors for the combined losses due to volatilization and denitrification shown in table 12.

Animal-Waste Decay Constants

When manure is applied to the same field year after year, the availability of N it contains becomes an important factor in determining application rate (108). Nitrogen becomes available to plants through the mineralization process. The N mineralization rate can be determined by using a series of decay constants described by Pratt et al (110). The process is rapid the first year after application and slows in subsequent years.

For example, a series of decay constants of 0.35, 0.15, 0.10, and 0.05 indicates that 35% of the N in the manure becomes available the first year, 15% of the residual N becomes available the second year, 10% the third year, and 5% the fourth year, and each following year. Carbon dioxide is lost to the atmosphere and N is converted to NH_4-, NO_2-, and NO_3-N. Animal wastes containing higher percentages of N have more rapid decay rates. In such wastes, equivalent amounts of N and C are mineralized. Poultry manures have high decay constants because

TABLE 11.—*Estimated nitrogen loss within 4 days after application from livestock or poultry manures with different application methods* (*165*)

Method of application	Type of waste	N volatilization loss
		%
Broadcast	Solid	21
	Liquid	27
Broadcast and immediately cultivated	Solid	5
	Liquid	5
Knifing	Liquid	5
Sprinkler irrigation	Liquid	25

TABLE 12.—*Multiplication factors to adjust livestock or poultry manure quantities for nitrogen volatilization and denitrification losses after the wastes are applied to the soil*

Hydrologic soil group	Manure management	
	Surface-applied	Soil incorporated
A (sandy)	1.33	1.05
B (sandy, silty loam)	1.33	1.18
C (shallow, relatively heavy soil)	1.33	1.33
D (heavy clay soils)	1.33	1.67

they are high in uric acid and urea, substances that readily release NH_4-N. Manures accumulated on outdoor lots or in storage exposed to the environment have low-decay constants because N may have been lost through runoff or volatilization of NH_3, or mixing with debris of low N content. Manures having a low N percentage are likely to have a high carbon to nitrogen ratio, C/N, and such manures may cause rapid immobilization of mineralized N by micro-organisms during the early part of the growing season. The N then would be released several months after application of the manure, once the C/N ratio decreases below the critical range. Table 13 shows the N decay constants used in this manual.

One equation based on the N content of a manure is easier to use than a series of decay constants to determine the amount of manure to supply the N needed. Mathers and Goss (74) derived an equation using the decay constants developed by Pratt et al. (110) and Willrich et al. (165). Derivation of this equation is shown in the Appendix, page 101, and the values derived are shown in table 14. Table 12, page 31, shows the amounts of N losses expected for the different hydrologic soil groups.

Values from tables 10, 12, and 14 can be used to estimate the manure needed for a crop. For example, use corn grown for silage on Group B land. (Table 12 shows the amounts of N losses expected for the different hydrologic soil groups. The corn uses 235 lb of N per acre (N for grain plus stover, table 10, p. 29)). Soil tests show that 35 lb of N is available in the soil. The amount of additional N needed is 235 − 35 = 200. The manure contains 1.75% N. Table 14 shows that 11.6 tons of manure with 1.5% N or 7.0 tons with 2% N are required to supply 100 pounds of N. Take the average [(11.6 + 7.0) ÷ 2 = 9.3] or 9.3, times the factor from table 12, page 31, for Group B land (1.18) times N needed in hundredweight (2). All of these multiplied equals 22 tons per acre.

TABLE 13.—*Decay constants used to estimate animal-manure nitrogen availability to crops, considering the entire cropping year for degradation of the manure*

Manure source	N in manure (dry-weight basis)	Decay constants in years after application			
		1	2	3	4
	%				
Poultry (hens) [1]	4.5	0.90	0.10	0.05	0.05
Poultry (broilers, turkeys) [2]	3.8	.75	.05	.05	.05
Swine [2]	2.8	.90	.04	.02	.02
Dairy, fresh [2]	3.5	.50	.15	.05	.05
Dairy, anaerobic [2]	2.0	.30	.08	.07	.05
Beef feeders, fresh [1]	3.5	.75	.15	.10	.05
Beef feeders, dry corral [1]	2.5	.40	.25	.06	.03
	1.5	.35	.15	.10	.05
	1.0	.20	.10	.05	.05

[1] Pratt et al. (110).

[2] Willrich et al. (165).

When the quantity of manure (tons/acre) needed to supply the desired quantity of N has been determined and the manure has been analyzed for other elements, a simple calculation will show the amount of other elements applied. For example, if N content is 1.5%, table 14 can be used to determine that 11.6 tons of dry manure are needed to supply 100 lb of N. If Zn concentration is 0.01%, then 11.6 x 2,000 x 0.0001 = 2.3 lb of Zn applied per 100 lb of N the first year, 9.0 x 2,000 x 0.0001 = 1.7 lb the second year, etc. The quantity of other elements can be determined in the same manner.

Nitrogen in feedlot runoff can be assumed to be largely available the first year, so no decay constant is needed in the calculations. For example, in table 7, page 22, dairy runoff is estimated to contain 0.015% N on a wet basis for Sample Problem 2. On Worksheet 2, page 23, the $160{,}000 \text{ gal} \times \frac{8.34 \text{ lb}}{\text{gal}} \times 0.00015 = 200$ lb of N. The rate at which the runoff is added will probably be governed by either the irrigation that the soil can use or the amount of salt that can safely be added to the soil, rather than by the amount of N that the runoff supplies. The volume, 160,000 gallons calculated in acre-inches, is $160{,}000 \text{ gal} \div \frac{27{,}150 \text{ gal}}{\text{acre-in}} = 5.9$ acre-in (see Appendix, p. 101, for derivation of the conversion constant).

Salinity Limitations

In areas with heavy rainfall and natural leaching, salinity (saline or salty soil) is not a problem; however, in irrigated and low-rainfall areas, application of materials containing salt must be limited (18, 19, 106, 109, 123, 137). The soil must be managed to minimize or prevent salt accumulation (75, 76).

TABLE 14.—*Quantity of livestock or poultry manure needed to supply 100 pounds of nitrogen over the cropping year*[1]

Length of time applied (years)	N in manure (%)									
	0.25	0.50	0.75	1.0	1.25	1.5	2.0	2.5	3.0	4.0
	Tons dry manure/100 lb N									
1	154.1	60.7	34.1	22.2	15.7	11.6	7.0	4.6	3.1	1.4
2	79.3	36.6	22.5	15.6	11.6	9.0	5.8	3.9	2.8	1.4
3	53.8	27.2	17.6	12.7	9.7	7.7	5.1	3.6	2.6	1.4
4	40.9	22.0	14.8	11.0	8.6	6.9	4.7	3.4	2.5	1.3
5	33.0	18.7	13.0	9.8	7.8	6.3	4.4	3.2	2.4	1.3
10	17.0	11.2	8.5	6.9	5.7	4.9	3.7	2.8	2.2	1.3
15	11.5	8.3	6.7	5.6	4.8	4.2	3.3	2.6	2.0	1.2
20	8.7	6.7	5.6	4.8	4.2	3.8	3.0	2.4	2.0	1.2

Since most irrigation water contains soluble salts, there are two sources of salt when animal wastes are applied to irrigated land (61).

Although the following salinity guidelines for use of manures are reliable in many situations, they may not be applicable if impermeable layers exist below the soil surface. Also, the values are based on specific soil water additions by precipitation or irrigation each year. If less water is used (as for dryland applications) or if soil or water characteristics are unusual, watch the application area closely. Monitor the salt-alkali status by yearly soil tests. Note the seed germination and crop growth, and observe whether water stands in the field longer than usual. If the local conditions deviate markedly from the circumstances described here, obtain local professional advice and help.

Soil salinity is determined by measuring the electrical conductivity of a saturated soil paste extract (EC_e). Soil with an EC_e of 4 mmhos/cm is considered saline. Soil saturated with 1 acre-ft of water containing 1,740 lb of salt would have an EC_e of 1.0 mmho/cm (140).

Figure 11 shows that corn yields are reduced by application of livestock or poultry manures at high rates. Figure 12 shows that the yield reduction was caused by salt buildup from heavy application rates (greater than 60 tons/acre). Corn is a crop with low tolerance to salinity and yield was affected when the EC_e value was 2 mmhos/cm. If salinity cannot be entirely controlled, salt-tolerant crops may produce satisfactory yields. Table 15 lists selected crops with very high, high, medium, and low salt tolerance (8). (Additional information is available in Agriculture Handbook No. 60, Diagnosis and Improvement of Saline and Alkaline Soils (140)). Salinity also can be controlled by use of certain land preparation and tillage methods, irrigation techniques to leach salts below the root zone, installation of drainage systems, and, in some instances, chemical additives to improve the soil structure.

How much salt can be applied safely to cropland depends on the quantity of rainfall or of good quality irrigation water available. Average annual precipitation or quality of irrigation water, manure salt content, and hydrologic soil group (soil texture) may be used to determine the maximum manure application rate. Figure 13 shows the leaching required to maintain a low salt level in the root zone ($EC_e < 4$ mmhos/cm in leachate) with manure applications less than 40 tons/acre. Figure 14 shows the leaching required for medium salinity status. An estimate of the average annual potential leaching (percolation) caused by precipitation for nonirrigated lands is shown on page 26 in Stewart et al. (126). For example, in most of the Great Plains, leaching ranges from 0.1 inch. In southeastern Georgia, it exceeds 7.1 inches. The percent salt in manure may be estimated by multiplying the combined percentages of K, Ca, Na, and Mg, as determined by laboratory analysis, by a factor of 2. (See table 7, page 22, for estimated percentage of salt in manures.) Electrical conductivity is used as a measure of salt level in irrigation water. When irrigation water has an EC

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[1] The values are for repeated application on the same acreage. An equation for calculation of the values is shown in the Appendix.

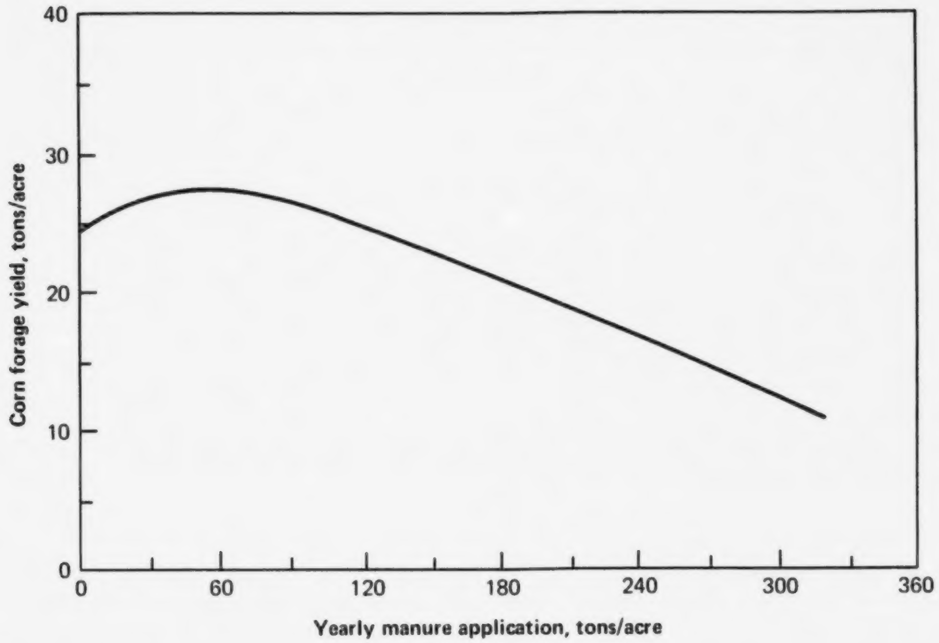

FIGURE 11.—Effect of applied manure (dry-weight basis) on corn forage yield (wet-weight basis) after three annual applications on irrigated soil.

of 1.0 mmho/cm, 1,740 lb of salt will be applied per acre with each foot of irrigation water. This amount of salt will require about 3 inches of leaching to maintain low salinity in the root zone.

For a sample calculation, assume the nonirrigated land is in the eastern part of the Great Plains, the leaching is 1 inch from annual precipitation, and the manure available for use is dairy manure with a salt content of 11.6%. Figure 13 can be used as follows: (a) find leaching required (1 inch) on the horizontal axis; (b) draw a vertical line to meet the curve on the graph for the salt content (about halfway between the curves for 10 and 12%); (c) the maximum dry manure rate in tons per acre shown on the vertical axis can be determined by drawing a horizontal line from this point to the vertical axis (about 2.5 tons/acre).

Under some circumstances, the proportions of Na and K in the manure or feedlot runoff water may promote soil structure deterioration (106, 107, 109). If the ratios of Na and K to the total salt in the manure or runoff are more than 0.39, 0.32, 0.30, and 0.24, the manure or runoff may cause dispersion of the soil aggregates when applied to hydrologic soil groups A, B, C, and D, respectively. However, data from the Imperial Valley indicate that manure applied at high rates to a fine-textured soil improved the infiltration rates for several years. Stewart and Meek (125) and Mathers et al. (77) report increased infiltration on fine-textured soils where manure was applied.

Group D soils are difficult to leach, and therefore, not more than 5 inches of leaching should be attempted during the season. Coarse-textured soils can be leached more. For illustrative purposes, it is assumed that Group A, B, C, and D soils require 10, 7, 6, and 5 inches of leaching to maintain a low-salinity status (106, 109, 140). Leaching, however, removes nitrate as well as other salts, and considerable energy is used in supplying irrigation water, so excessive amounts of manure should not be applied to cropland with the intention of later leaching excessive amounts of salts.

For a sample calculation, assume 20 inches of irrigation water with an EC of 0.6 mmhos/cm are applied and the manure contains 11.4% salt. Note the legend in figure 13 states that 3 inches of leaching are needed for each foot of irrigation water having

TABLE 15.—*Tolerance level and effect of salt on yields of crops*[1]

Crop	Tolerance levels[2]	Yield reduction		
		None	10%	50%
		EC_e[3]		
Bermudagrass	VH	6.9	10.8	14.7
Barley	VH	[4] 8.0	[4] 10.0	18.0
Tall wheatgrass	VH	7.5	9.9	19.4
Crested wheatgrass	VH	3.5	9.8	16.0
Cotton	VH	7.7	9.6	17.0
Barley (hay)	VH	6.0	9.5	13.0
Sugar beets	VH	[4] 7.0	[4] 8.7	15.0
Wheat	H	[4] 6.0	[4] 7.4	13.0
Perennial rye	H	5.6	6.9	12.2
Safflower	H	5.3	6.2	9.9
Birdsfoot trefoil	H	5.0	6.0	10.0
Hardinggrass	M	4.6	5.9	11.1
Tall fescue	M	3.9	5.8	13.3
Soybean	M	5.0	5.5	7.5
Sorghum	M	4.0	5.1	11.0
Beardless wild rye	M	2.7	4.4	11.0
Rice (paddy)	L	3.0	3.8	7.2
Sesbania	L	2.3	3.7	9.4
Alfalfa	L	2.0	3.4	8.8
Orchardgrass	L	1.5	3.1	9.6
Broadbean	L	1.6	2.6	6.8
Corn	L	1.7	2.5	5.9
Flax	L	1.7	2.5	5.9
Meadow foxtail	L	1.5	2.5	6.7
Clover	L	1.5	2.3	5.7
Beans (field)	L	1.0	1.5	3.6

[1] Adapted from Ayers and Wescot (8).

[2] Tolerance levels based on EC_e for 10% yield reduction: 8–13, VH (very high); 6–7.9, H (high); 4–5.9, M (medium); 1–3.9, L (low).

[3] EC_e means electrical conductivity of saturation extract in mmhos/cm, and is an indication of the total salt content of a soil.

[4] Tolerance during germination (beets) or early seedling stage (wheat, barley) is limited to EC_e about 4 mmhos/cm.

an EC of 1 mmho/cm. Therefore, 20 in x 1 ft/12 in x 3 in/1 ft x 0.6 = 3 in of leaching is needed for the salt in the irrigation water in this example. If the total leaching is 10, 7, 6, and 5 inches for Group A, B, C, and D soils, respectively, that leaves 7, 4, 3, and 2 inches of effective leaching to remove the manure salts. In figure 13, those leaching values correspond to 20, 12, 8, and 6 tons of dry manure per acre, respectively.

Runoff water from feedlots has some nutrient value and will increase the yield of most crops until salt buildup. To prevent salt accumulation, the irrigator should dilute runoff waters from feedlots with good quality irrigation water. The quantity of irrigation water required for a given amount of feedlot runoff water depends on the electrical conductivity of both waters, the hydrologic soil group, and the desired soil salinity level. Figure 15 shows the number of inches of irrigation water to add to an inch of feedlot runoff water. The procedure is: (a) find the electrical conductivity (assume 3.0 mmhos/cm) of the feedlot runoff water on the vertical axis of the graph; (b) move horizontally to the curve corresponding to the electrical conductivity of the irrigation water (assume 0.5 mmho/cm); and (c) finally, move down to find the proper dilution factor or the number of inches of irrigation water (4 inches) to add to each inch of feedlot runoff water. The two waters should be mixed before application to the soil. Note that these values apply to a soil with a 25% leaching fraction intended to maintain a low-salinity soil. Figure 16 may be used for a leaching fraction of 15% to maintain medium-salinity soil.

The contribution of manure to the salt in drainage water will depend mostly on the Na content of the manure (77). If irrigation field runoff is used in an irrigation return flow system, salt in the water increases slightly due to salt removed from the soil and to evaporation. The use of manure, however, does not cause a significant increase of salt in these return flow systems (77). When drainage water is returned to the irrigation system the increase of salt depends on the leaching fraction. Water from drainage systems may need to be diluted with low-salt water before reuse.

Worksheet 3 Instructions

Worksheet 3 is used to determine the land-application rate of manures and feedlot runoff that can be used to supply N for crops without creating salinity problems. The following Steps 1 through 6 correspond to Steps 1 through 6 on the worksheet.

1. Use figure 4, page 8, to determine the Land Resource Area of the livestock or poultry site. Supply the following information for site evaluation.
    1a. Is topography flat, rolling, or steep? (If specific information is not available, consult local SCS, county extension agents, or Agriculture Handbook 296 (7).)

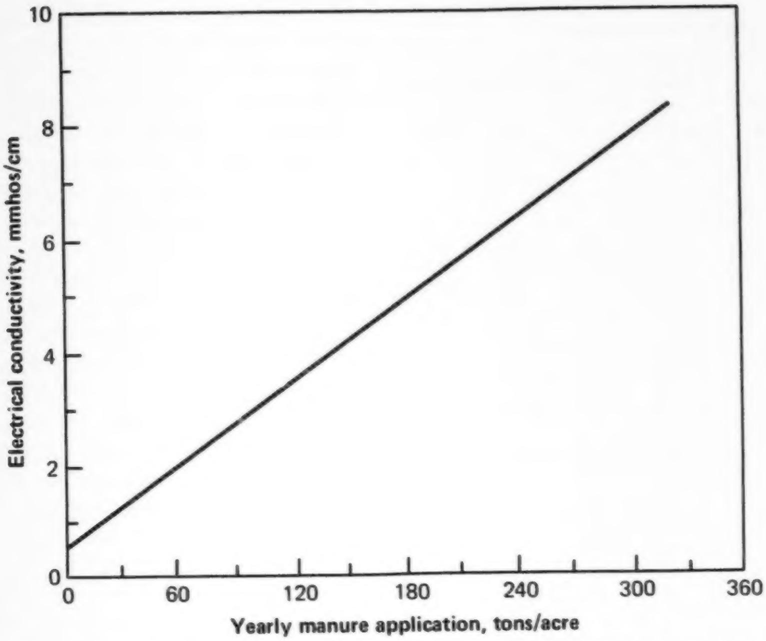

FIGURE 12.—Salt buildup in irrigated soil resulting from three annual manure applications. Manure rates on dry-weight basis.

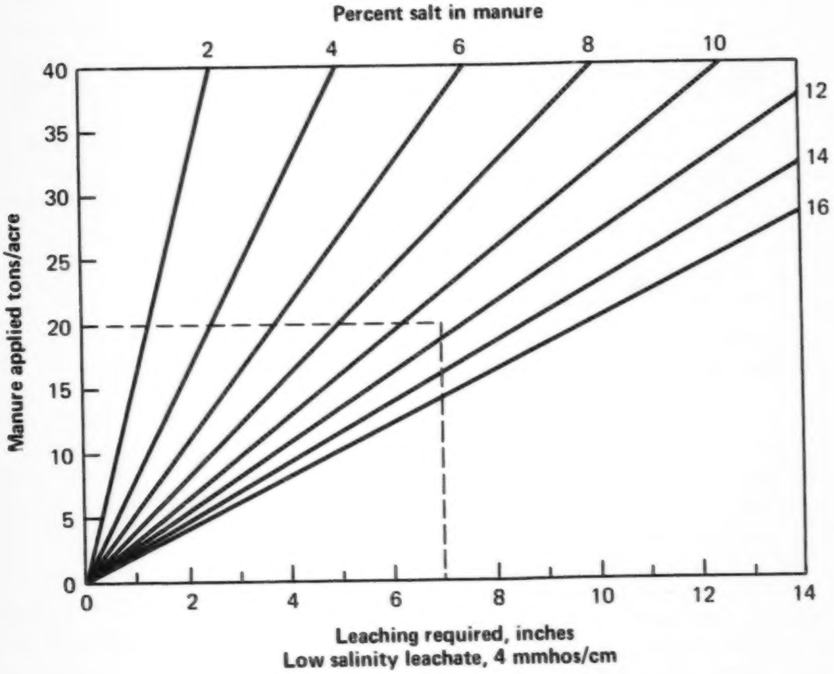

FIGURE 13.—Estimated annual livestock or poultry manure application (dry-weight basis) allowable on cropland to maintain low-salinity level.

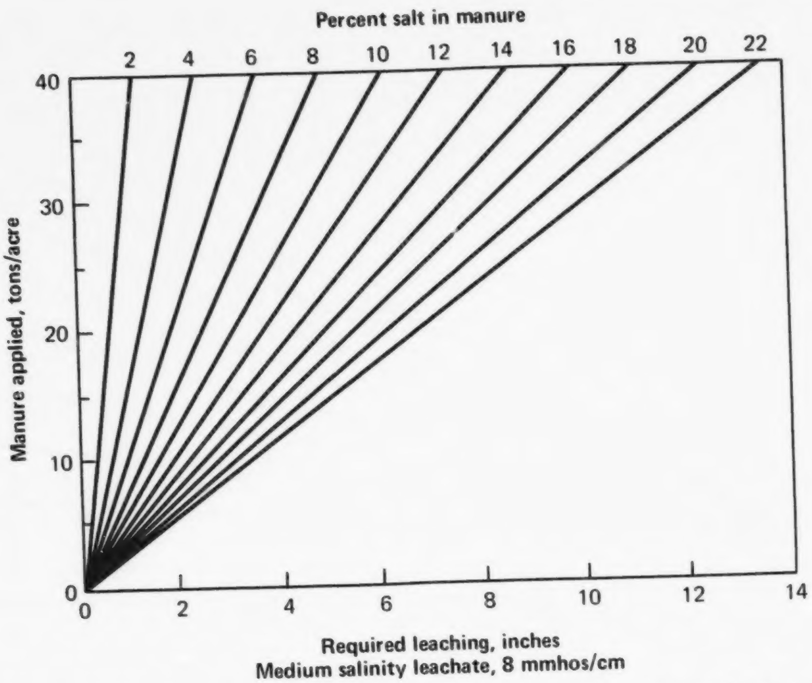

FIGURE 14.—Estimated annual livestock or poultry manure application (dry-weight basis) allowable on cropland to maintain medium-salinity level.

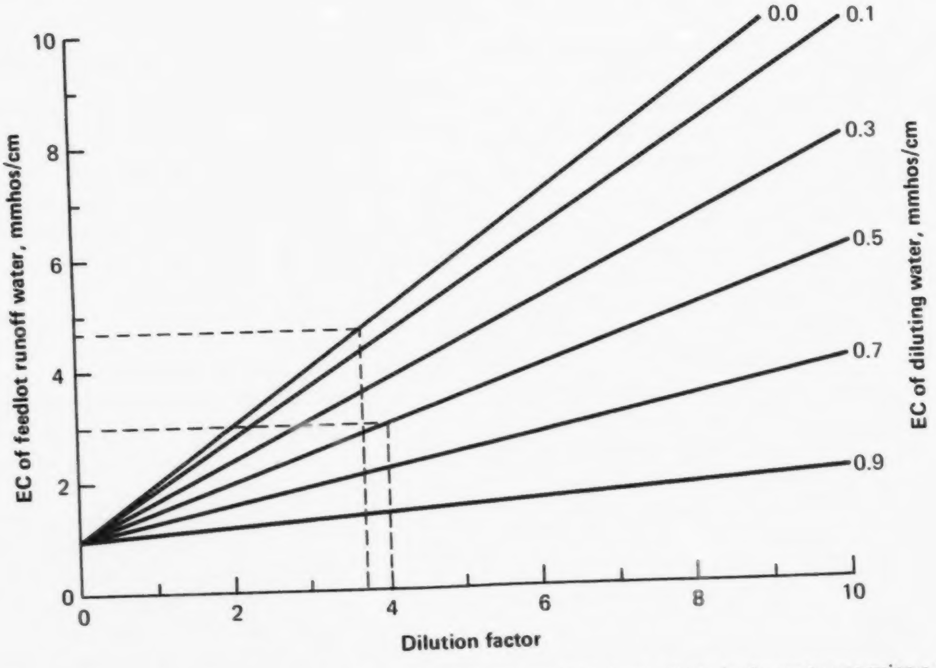

FIGURE 15.—Estimated dilution factors for feedlot runoff water to maintain low salinity in the root zone using a 25% leaching fraction.

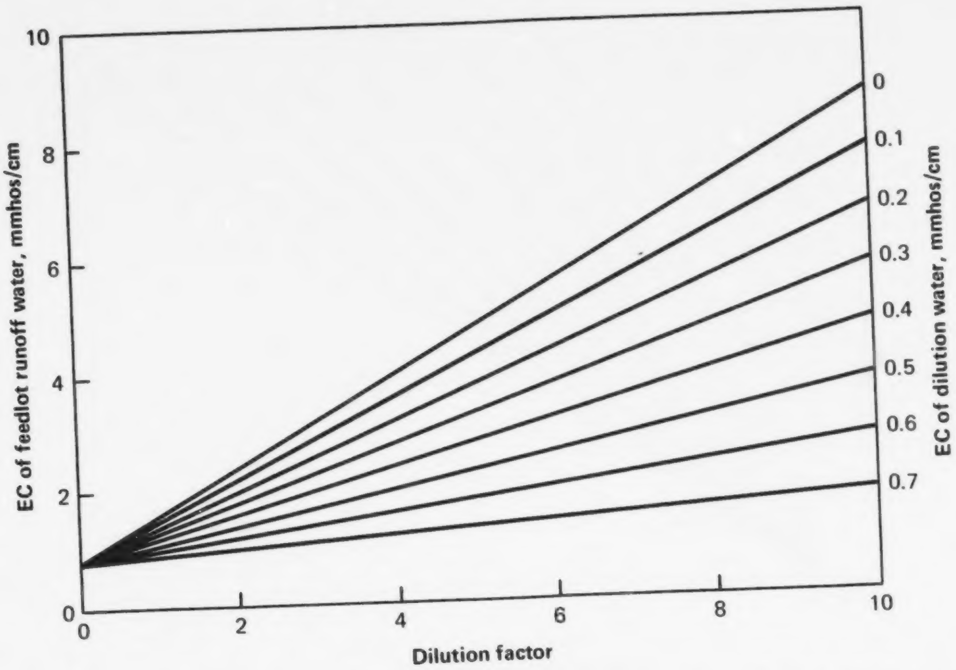

FIGURE 16.—Estimated dilution factors for feedlot runoff water to maintain medium salinity in the root zone using a 15% leaching fraction.

1b. Are conservation measures used? (Consult SCS or Extension Service.)

1c. Is the hydrologic soil Group A, B, C, or D? (See Section 4, p. 28, for explanation of hydrologic soil groups.)

1d. Is the site irrigated?

  1d.1. Is surface water or ground water used for irrigation?

  1d.2. What is the electrical conductivity of the irrigation water? (Contact SCS or county agent for local testing information.)

1e. Use figure 6, page 11, and table 6, page 21, to obtain climate and precipitation.

1f. Use table 9, page 27, to determine when manure application is most likely.

1g. Is manure applied to the surface or is it incorporated into the soil by plowing or injection?

1h. Is the crop grass, small grain, or a row crop?

1i. Enter whether land is plowed and, if so, when.

2. Use the following procedure to determine application rates.

  2a. Use table 10, page 29, to determine the N content of the crop to be grown. If crop is divided into grain and stover or grain and straw, etc., add the N required by each part of the crop if the entire plant is used. Adjust quantities according to expected yield.

  2b. To determine the N available in the soil, contact a county extension agent or SCS for soil test information.

  2c. Determine the N needed from manure.

    2c.1. Subtract Line 2b (N available in soil) from Line 2a (N content of crop).

    2c.2. Divide the answer on line 2c.1 by 2. Dividing by 2 limits the manure rate to one-half of the amount needed, with the rest of the N supplied by commercial fertilizer.

  2d. Transfer the manure sources from Worksheet 2 to Line 2d. Fill in percent N from local analysis or regional data known to fit the management system or use Table 7, page 22, for an estimate.

2d.1. Fill in manure amount required to supply 100 lb of N from table 14, page 33. Fill in multiplication factor for hydrologic soil group from table 12, page 31. Find recommended dry rate by multiplying (column 3 by column 4 by Line 2c.2 by $\frac{1}{100}$) rate to supply 100 lb N times multiplication factor times N needed from manure (pounds/acre) divided by 100. Find recommended wet rate by dividing the needed dry manure weight by the fractional dry weight of the manure (dry weight/wet weight from analysis of estimate), i.e., $10.98 \div \frac{1.90}{10.56} = 61.05$ (≈ 61) tons.

2d.2. When using feedlot runoff or lagoon effluent, the calculations for rate can yield gallons/acre or acre-inches, depending on the convenience of the unit for volume. It is assumed that soluble N in the runoff is 100% available. Calculate the number of gallons needed to supply 100 lb of N and enter that in column 3. For Sample Problem 2, $160{,}000 \text{ gal} \times \frac{8.34 \text{ lb}}{\text{gal}} \times 0.00015 = 200$ lb of N. Then, $\frac{160{,}000 \text{ gal}}{200 \text{ lb N}} \times 100 = 80{,}000$ gals for each 100 lb of N. Find recommended gallons for column 5 by multiplying (column 3 by column 4 by Line 2c.2 by $\frac{1}{100}$) rate to supply 100 lb N times multiplication factor times N required (pounds/acre) divided by 100. To convert gallons/acre to acre-inches, divide by 27,150 for column 6, wet-rate, runoff water.

3. Determine the salinity hazard of the recommended rate.

3a. Find the percent salt content or electrical conductivity of each manure source from local data, analyses, or table 7, page 22.

3b. Use figure 13, page 36, or figure 14, page 37, to determine salinity limitations based on salt in the manure (Line 3a).

3b.1. Assume 10, 7, 6, and 5 inches of leaching on Group A, B, C, and D soils, respectively, for low salinity status. For nonirrigated soils, determine the average annual potential leaching from Stewart et al. (126) or from data from the SCS or state university extension sources. Record this value for leaching on Line 3b.1.

3b.2. Use figure 15, page 37, to determine the dilution factor for feedlot runoff or lagoon effluent to irrigate with a 25% leaching fraction to maintain low salinity, or figure 16, page 38, to maintain medium salinity with a 15% leaching fraction (see Glossary and Section 4, pp. 32-35).

3c. *For nonirrigated land,* figure 13, page 36, or figure 14, page 37, should be used to determine the total application rate allowable before soil salinity becomes a problem. Note the annual estimated leaching (obtained in Step 3b.1). The application rate to maintain low soil salinity (with a given manure salt content) varies with the leaching. Use the leaching listed on Line 3b.1 and the manure salt content to determine the limiting application rate from figures 13 or 14. For feedlot runoff (diluted to maintain low salinity at 25% leaching fraction), the limiting rate is determined by the amount of irrigation the land will accept without excessive runoff or leaching potential or N supplied in the feedlot runoff. These factors will have to be evaluated individually. Record the application rate on Line 3c.

3d. *For irrigated land,* use figures 13 or 14, pages 36 and 37. The application limit to maintain low soil salinity will depend on the leaching required for the hydrologic soil group and the electrical conductivity (EC) of the irrigation water. Find the leaching list on Line 3b.1. Use the EC of the irrigation water (Line 1d.2). At the base of figure 13, at the correct leaching value, draw a vertical line to the diagonal line representing the correct percent salt in the manure (Line 3a). The same procedure for either a lagoon or feedlot runoff holding pond is used here as for Step 3c. Record the limiting application to maintain low salinity on Line 3d.

3e. Find whether the crop to be planted on the site has a very high, high, moderate, or low tolerance to salinity in table 15, page 35.

3f. Determine other potential limitations on application rates, such as possible soil structure deterioration and animal or human health hazards (see Section 4, p. 30).

4. The limiting loading rate is either Line 2d or Line 3c (if land is nonirrigated) or 3d (if land is irrigated), whichever is less.

5. Because the agronomic loading rate has been limited by supplying only a fraction of the N needed or by salinity problems, the amount of supplementary fertilizer must be determined.

   5a. First, find the actual amount of N in the manure to be applied. To do this, multiply the limiting application rate (Line 2d, 3c, or 3d) by the quantity

$$\frac{\text{100 lb N/acre}}{\text{column 3 times column 4 (Line 2d)}}$$

   Record the result on Line 5a.

   5b. The amount of supplemental N needed in the form of commercial fertilizer may be determined by using information from Line 2c.1 (N needed) and Line 5a (actual N applied). For each manure source, subtract Line 5a from Line 2c.1. The resulting number is the amount of supplemental N required in lb/acre.

6. Determining the number of acres needed to spread the manure at agronomic rates is the final step.

   6a. List the source of the manure and the amount of manure available yearly (tons/year) (Worksheet 2). Divide the amount available (Worksheet 2) by the application rate (line 4). The number calculated is the area (acres) required for land application of the manure.

   6b. Add the area requirements for each source to determine the total area (acres) required for manure application at agronomic rates.

SAMPLE PROBLEM 2

WORKSHEET 3 Determining Application Rate of Livestock or Poultry Manure to Land [1]

1. Location (LRA, Figure 4, page 8) 95

1a Topographic Features .... ___ Flat ✓ Rolling ___ Steep Slope

1b Conservation Practices .... ___ Yes ✓ No ___ Unknown

1c Hydrologic Soil Group (Section 4, page 28; Table 17, page 45) ___ A ✓ B ___ C ___ D

1d Irrigation .... ___ Yes ✓ No

If yes:

1d.1 Water Source .... ___ Ground water ___ Surface water

1d.2 Water Electrical Conductivity (EC) (mmhos/cm) .... ___ ___

1e Climate (Figure 6, page 11) .... ✓ cold; ___ cool; ___ warm; ___ hot; ___ arid; ✓ humid

Maximum (Average) Annual Precipitation (Table 6, page 21).. 32 inches/year

1f Application time [circle most probable months] (Table 9, page 27) J F M A [✓ M J J A S] O N D

1g Method of application .... ✓ Surface ___ Soil incorporate ___ Unknown

1h Type of cropping system corn silage or grain + stover .... ___ Grass ___ Small grain ✓ Row ___ Plowed field

1i Other considerations:

1i.1 Is land plowed .... ✓ Yes ___ No ___ Unknown

1i.2 If yes, when .... ___ Spring ✓ Fall ___ Unknown

2. Agronomic Application Rates

2a N content of crop[1] (Table 10, page 29) .... 235 lb/acre

2b N available in soil (soil test)[2] .... 0 lb/acre

2c N needed from manure

2c.1 Needed [N content of crops (line 2a) - N available in soil (line 2b)] .... 235 lb/acre

2c.2 N needed from manure (line 2c.1 divided by 2)[3] .... 118 lb/acre

2d Recommended Dry and Wet Rates (Table 7, page 22)

Manure Source (Worksheet 2)	Percent N (local analysis or Table 7, page 22)	Manure needed to supply 100# N (Table 14, p. 33, or calculated vol., p. 32)	Multiplication Factor (Table 12, page 31)	Recommended Dry Rate or Volume (col. 3 x col. 4 x $\frac{\text{manure N}}{100}$)	Recommended Wet Rate (calculate from col. 5)[4]
(1)	(2)	(3)	(4)	(5)	(6)
		rate/acre		rate/acre	rate/acre
Stored	2.0	7.0 tons	1.33	10.98 tons or 11 tons	61 tons
Effluent	0.015	80,000 gallons or 2.94 acre-in	1.33	125,000 gal	4.6 inches

See footnotes at end of Worksheet.

SAMPLE PROBLEM 2

Worksheet 3 (continued).

3. Loading rate limitations

Salinity limits

Manure source (Worksheet 2) Stored ______ Runoff

3a Manure salt content (%) or Runoff electrical conductivity (EC in mmhos/cm) (Table 7, p. 22) 11.6 % ______ % 4.7 mmhos/cm

3b Salinity calculations

3.7 + 1 = 4.7

3b.1 Leaching required for soil for low salinity status (Text, pages 32-35) 7 inches ______ inches $\frac{6.0}{4.7} \times 1.0 = 1.3$

3b.2 Irrigation water to dilute runoff (Figures 15 and 16, pages 37 and 38) 6.0 - 1.3 = 4.7 inches/1.3 inches of runoff (rainwater)

3c Nonirrigated land limiting application rate (Figures 13 and 15, pages 36 and 37) 17 tons/acre (dry) ______ tons/acre (dry) 1.3 inches/acre (undiluted runoff in

3d Irrigated land limiting application rate (Figures 13 and 15, pages 36 and 37) ______ tons/acre (dry) ______ tons/acre (dry) ______ inches/acre-ft irrigation 6" of irrig)

3e Crop tolerance to salinity (Table 15, page 35) ______ very high; ______ high; ______ medium; ✓ low;

Other limitations (grass tetany, fat necrosis, etc.) Explain: No history of other problems (county extension agent)

Manure Source............... stored ______ runoff

4. The limited application rate is the lesser quantity shown on lines 2d or 3c (nonirrigated) or 3d (irrigated) .... 10.98 or 11 tons/acre (dry) ______ tons/acre (dry) 1.3 in/acre

5. Because of the limited application rate, determine the supplemental fertilizer required: ______ in/acre-ft irrigation

5a Actual N applied in manure: limiting application rate (lines 2d, 3c, or 3d) x 100 / adjusted app. rate (line 2d or col. 3 x col. 4) = Actual N applied

7.0 × 1.33 = 9.31
2.94 × 1.33 = 3.91

Manure Source	Stored	10.98	x	100 / 9.31	=	118 lb N/acre
	Runoff		x	100 / 3.91	=	33 lb N/acre
			x	100	=	lb N/acre

5b Supplemental N required: N needed (line 2c.1) - N applied (line 5a) = supplemental N required

Manure Source	Stored	235	-	118	=	117	lb N/acre
	Runoff	235	-	33	=	202	lb N/acre
			-		=		lb N/acre

See footnotes at end of Worksheet.

(continued)

Worksheet 3. (conclusion).

6. Application area

6a	Manure source (from worksheet 2)	Available quantity (worksheet 2)	÷	Application rate (line 4) (rate/acre)	=	Area required (acres)
	Stored	190 tons	÷	11 tons (dry)	=	17.3
	Runoff	160,000 gal	÷	1.3 in	=	4.5
		or 5.9 acre-in	÷		=	

6b Total application area (add all areas required for each manure source) = 21.8

---

[1] Nitrogen required by crops must be adjusted to correspond to expected yields and N content for the area and soils if different from Table 10.

[2] Contact County Extension and Soil Conservation Service offices for local information. Use Agriculture Handbook 296 for general information for Land Resource Areas.

[3] Assuming one-half of the N needed is to come from the manure. Any other convenient fraction could be assigned to the quantity of N to be derived from the manure source. See text, page 30 .

[4] Recommended wet weight quantities are expressed in tons of manure. To obtain gallons of manure, multiply by 240 $\left[\frac{2000\ \text{lb}}{1\ \text{ton}} \times \frac{1\ \text{gal}}{8.34\ \text{lb}} = \frac{240\ \text{gal}}{1\ \text{ton}}\right]$. To convert gal/acre to in/acre, divide by 27,150 gal/acre-in. To calculate wet weight from dry weight of solids, divide column 5 by the fractional dry weight.

Section 5

WATER QUALITY

Application of livestock and poultry manures may affect the quantity and quality of runoff and leachate from agricultural lands. This section does not indicate what the maximum acceptable values are for environmental quality, nor does it attempt to evaluate runoff or percolate values derived by the procedures. *Best usable values* are provided to enable planners to estimate quantity and quality of runoff solution and leachate. These values do not indicate the effect of runoff and leachate on water quality after they leave the field where manures have been applied.

Runoff Quantity

Runoff from rainfall and snowmelt has enough energy to transport huge quantities of soil. The quantity of soil transported is affected by climate, rainfall characteristics, antecedent moisture conditions, soil infiltration potential, cropping, and conservation practices. Soil Conservation Service procedures (141) were used in this manual to estimate runoff quantities for small grain, row crops, and grassland within LRA's.

Antecedent moisure condition (AMC) is defined as the amount of water stored in the soil on the day of a storm and is determined by the total rainfall accumulation during the preceding 5 days. Table 16 shows the three AMC groups used. The driest watershed conditions (AMC Group I) are when the soil is dry enough for satisfactory plowing or cultivation. Average watershed conditions are in Group II, and watershed conditions nearly saturated from rains during the previous 5 days are in Group III. Group III has the highest runoff potential. The 5-day rainfall amounts stored in the soil for each group vary with geographic location and season as a result of evapotranspiration.

TABLE 16.—*Seasonal rainfall limits for antecedent moisture conditions used in runoff calculations (141)*

Antecedent moisture content	Total 5-day antecedent rainfall	
	Dormant season	Growing season
	Inches	Inches
I	less than 0.5	less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	more than 1.1	more than 2.1

Infiltration potential is represented by the soil index of hydrologic soil groups (A through D) and is determined by the minimum infiltration rate of bare soil after prolonged wetting (91). See Section 4, page 28, for approximate infiltration rates of hydrologic soil groups.

Hydrologic soil groups with different land uses and treatments are called hydrologic soil-cover complexes. Each complex has a runoff potential for the average antecedent soil moisture condition, depending on soil water-holding capacity, infiltration rate, and foliage interception. The term "hydrologic condition" refers to the runoff potential of a particular cropping practice. A crop under good hydrologic conditions will have a higher infiltration rate and subsequently lower runoff potential than the same crop under poor hydrologic conditions.

Table 17 shows estimated average annual runoff quantities for grassland, small grain crops, and row crops. The values were developed using the SCS curve number method in conjunction with procedures developed by Stewart et al. (126, 127). The percentage of snowmelt runoff (table 17) was estimated by using a map of January normal daily maximum temperatures (147). Snowmelt runoff was assumed to be significant north of the maximum 45° January isotherm (fig. 6, page 11). Snowmelt runoff estimates were based on limited data from Missouri, Iowa, Minnesota, Pennsylvania, and Vermont.

Livestock and poultry manures applied to cropland affect runoff quantity by changing the infiltration rate and increasing the water-holding capacity (field capacity) of the soil. Runoff is usually reduced when livestock or poultry manures are applied to land (51, 71, 168, 169), although cases of increased runoff have been reported (107). *It is assumed that rainfall and snowmelt runoff values shown in table 17 are reduced 5% and 20%, respectively, by surface application of livestock and poultry manures.*

For example, assume that animal wastes are surface-applied at agronomic rates to 100 acres of wheat in LRA 106. The annual runoff for LRA 106 is estimated to be 1.0 inch, with snowmelt contributing

TABLE 17.—*Estimated average annual runoff from grass, small grain, and row cropland without applied livestock or poultry manure by Land Resource Area*

Land Resource Area [1]	Hydrologic soil group	Average annual runoff [2]			
		Grass	Small grain	Row crop	Amount due to snowmelt
			inches		%
52	B	<1	<1	<1	50
53	B	<1	<1	<1	50
54	B	<1	<1	<1	50
55	B	<1	<1	<1	50
56	D	1.8	2.35	2.9	50
57	B	<1	1.0	1.5	50
58	B	<1	<1	<1	30
59	C	<1	<1	<1	50
60	D	<1	1.0	1.3	30
61	B	<1	<1	<1	30
62	MTNS [3]	—	—	—	—
63	D	1.4	1.9	2.4	40
64	B	<1	<1	<1	10
65	A	<1	<1	<1	10
66	B	<1	1.0	1.4	10
67	B	<1	<1	<1	5
68	B	<1	<1	<1	5
69	B	<1	<1	<1	—
70	C	<1	1.0	1.3	—
71	B	<1	1.0	1.6	10
72	B	<1	1.0	1.4	5
73	B	<1	1.0	2.0	5
74	B	<1	1.0	2.6	5
75	B	<1	1.0	2.6	10
76	D	5.0	5.75	6.5	5
77	C	1.3	1.85	2.4	—
78	C	2.2	2.8	3.4	—
79	A	<1	1.0	1.4	—
80	C	3.1	3.75	4.4	—
81	D	2.2	2.8	3.4	—
82	C	3.1	3.75	4.4	—
83	D	4.1	4.8	5.5	—
84	B	1.5	2.55	3.6	—
85	D	6.0	6.75	7.5	—
86	D	7.0	7.75	8.5	—
87	D	8.0	8.75	9.5	—
88	FOR [3]	—	—	—	—
89	FOR	—	—	—	—
90	B	<1	1.0	1.5	50
91	A	<1	1.0	<1	50
92	FOR	—	—	—	—
93	FOR	—	—	—	—

(See footnotes at end of table.)

TABLE 17.—*Estimated average annual runoff from grass, small grain, and row cropland without applied livestock or poultry manure by Land Resource Area*—Continued

Land Resource Area [1]	Hydrologic soil group	Average annual runoff [2]			
		Grass	Small grain	Row crop	Amount due to snowmelt
		inches			%
94	FOR	—	—	—	—
95	B	<1	1.0	2.3	40
96	A	<1	1	1	30
97	B	<1	1.0	2.6	30
98	B	<1	1.0	2.5	30
99	D	3.6	4.25	4.9	30
100	B	<1	1.0	2.5	15
101	B	<1	1.0	2.3	25
102	B	<1	1.0	1.8	50
103	B	<1	1.0	2.0	50
104	C	2.6	3.25	3.9	40
105	B	<1	1.0	2.2	40
106	B	<1	1.0	2.7	10
107	B	<1	1.0	2.3	20
108	B	<1	1.0	2.3	25
109	C	3.2	3.90	4.6	10
110	C	3.2	3.75	4.4	15
111	C	4.0	4.75	5.5	10
112	D	6.0	6.75	7.5	—
113	D	6.0	6.75	7.5	5
114	D	7.0	7.75	8.5	5
115	B	1.5	2.55	3.6	5
116	C	5.9	6.70	7.5	—
117	MTNS	—	—	—	—
118	D	10.9	11.70	12.5	—
119	MTNS	—	—	—	—
120	C	5.0	5.75	6.5	5
121	C	5.0	5.75	6.5	5
122	B	3.1	4.40	5.7	—
123	C	8.3	9.15	10.0	—
124	C	3.1	3.75	4.4	5
125	MTNS	—	—	—	—
126	C	3.1	3.75	4.4	10
127	MTNS	—	—	—	—
128N[4]	B	2.3	3.50	4.7	—
128S	B	4.7	6.25	7.8	—
129	B	5.6	7.20	8.8	—
130	MTNS	—	—	—	—
131N	D	8.9	9.70	10.5	—
131S	D	15.8	16.65	17.5	—
132	D	12.8	13.65	14.5	—
133	B	3.9	5.35	6.8	—
134N	C	6.8	7.65	8.5	—
134S	C	11.7	12.6	13.5	—

(See footnotes at end of table.)

TABLE 17.—*Estimated average annual runoff from grass, small grain, and row cropland without applied livestock or poultry manure by Land Resource Area*—Continued

Land Resource Area [1]	Hydrologic soil group	Average annual runoff [2]			
		Grass	Small grain	Row crop	Amount due to snowmelt
		inches			%
135	D	15.8	16.65	17.5	—
136N	B	1.5	2.55	3.6	—
136S	B	4.7	6.25	7.8	—
137	A	<1	1.0	2.6	—
138	B	5.6	7.2	8.8	—
139	C	2.2	2.8	3.4	10
140	C	2.2	2.8	3.4	25
141	C	3.1	3.75	4.4	30
142	D	4.1	4.80	5.5	50
143	MTNS	—	—	—	—
144	A	<1	1.0	1.4	30
145	B	1.5	2.55	3.6	15
146	C	4.0	4.75	5.5	50
147	B	<1	1.0	2.6	10
148	C	3.1	3.75	4.4	10
149	C	4.0	4.75	5.5	5
150W	D	6.0	6.75	7.5	—
150E	D	15.8	16.65	17.5	—
151	SWMP [3]	—	—	—	—
152	D	15.8	16.65	17.5	—
153	C	7.8	8.65	9.5	—
154	A	1.5	3.70	5.9	—
155	B	7.4	9.15	10.9	—
156	SWMP	—	—	—	—

[1] It is not possible to estimate runoff for mountain, swamp, and forest regions or those with erratic climate.

[2] Average rainfall and snowmelt runoff values for land with surface-applied livestock or poultry manure may be calculated by multiplying listed values by 0.95 and 0.80, respectively. Listed values will not change when the manure is soil-incorporated.

[3] Mountains, MTNS; Forest, FOR; Swamps, SWMP.

[4] North, N; South, S; East, E; West, W, respectively within Land Resource Areas.

10% of the total (table 17). The total volume of runoff from the wheat field without manure applied or with animal manure incorporated would be 100 acre-inches:

Total Annual Runoff =
100 acres × 1.0 inch = 100 acre-inches

Snowmelt Runoff =
(100 acre-inches) (0.10) = 10 acre-inches

Rainfall Runoff = 100 — 10 = 90 acre-inches

Total volume of runoff from the wheat field with surface-applied waste would be:

Snowmelt Runoff = (10) (0.80) = 8.0 acre-inches
Rainfall Runoff = (90) (0.95) = 85.5 acre-inches
Total Annual Runoff = 93.5 acre-inches

(Recall from p. 44 that surface-applied manure reduces rainfall and snowmelt runoff 5 and 20%, respectively.) The net runoff reduction as a result of *surface-applied* livestock or poultry manure is about 6.5% for the field in this example.

Runoff Quality

It is difficult to estimate the quantities of total N, total P, and COD in solution in runoff that can be attributed to land application of livestock and poultry manures (107). Little definitive data are available on the chemical composition of surface runoff from agricultural lands with or without manures applied because variations in soil and vegetation significantly affect concentrations of dissolved chemicals in runoff.

Suspended and soluble solids and debris are transported in runoff as sediment. These materials are potential surface water pollutants. Almost all of the N and P lost from agricultural lands are associated with sediment (22, 134). These losses are a function of the N and P concentrations in the soil and an enrichment factor (13), which results from the fractionation and accounts for the enrichment of sediment during the erosion process. In this manual, the soluble, increased amounts of N, P, and COD values in runoff tables are considered to be derived only from surface-applied livestock and poultry wastes rather than sediment values. In other words, the values reported with the runoff here are in addition to the losses that are part of the sediment.

Excluding organic soils, most U.S. soils contain from 0.05 to 0.30% N (122). The agricultural soils in the upper Midwest are highest in N, generally ranging from 0.2 to 0.3% (4 to 6 lb/ton); soils in most other U.S. areas have N levels of 0.05 to 0.2% (1 to 4 lb/ton). An enrichment factor for N in eroded soil has been found to vary from about 1.1 to 5.0 (13). However, the enrichment factor is conservatively estimated at 2.0. From this, an N loss of 8 to 12 pounds of N per ton of soil in the upper Midwest and 2 to 8 pounds of N per ton of soil for most other U.S. cropland can be assumed.

Phosphorus concentration in U.S. agricultural soils is estimated to be about 0.05% (1 lb/ton). The enrichment factor for P in eroded soil has been found to range from 1.3 to 3.1 (13). If an enrichment factor of 2 is assumed, the average P loss in eroded soil is estimated to be 2 pounds per ton of soil.

Livestock and poultry manures applied to agricultural land at agronomic loading rates can reduce erosion potential. Surface applications of 3 tons or more per acre (d.b.) can reduce soil loss from sloping land by 50 to 80% (11, 168, 169). Since most of the eroded N and P is associated with the sediment, manure applications may substantially reduce the total runoff transport from row cropland (13, 158).

Table 18 represents the best usable values for dissolved N, P, and COD concentrations in runoff water from land to which manures were applied to the surface. These estimated values were obtained from published data (27, 51, 71, 81, 107, 168, 169). Values for dissolved N, P, and COD concentrations have been listed separately for rainfall and snowmelt runoff (table 18). The following equation was used

TABLE 18.—*Estimated concentrations of total nitrogen, total phosphorus, and chemical oxygen demand dissolved in runoff from land with and without livestock or poultry manure surface-applied*[1] *at agronomic rates*

Cropping condition	Rainfall runoff						Snowmelt runoff		
	Total N		Total P		COD		Total N	Total P	COD
	Manure With	Manure Without	Manure With	Manure Without	Manure With	Manure Without	With manure		
	Parts per million								
Grass	11.9	3.2	3.0	0.44	360	50	36	8.7	370
Small grain	16.0	3.2	4.0	0.40	170	20	25	5.0	270
Row crop	7.1	3.0	1.7	0.40	88	55	12.2	1.9	170
Rough plow	13.2	3.0	1.7	0.20	88	55	12.2	1.9	170

[1] Incorporating manure in the soil would result in element concentrations the same as those for "without manure."

to estimate quantities of N, P, and COD transported in runoff from land with or without livestock or poultry manure applied:

$$W_X = 0.226\ RC$$

where W_X = quantity of element transported (lb/acre)

R = runoff (inches)

C = runoff concentration (parts per million)

The constant, 0.226, is a conversion factor with units of lb/acre-in. Runoff in inches (R) from table 17 and concentration in parts per million (p/m) (C) for dissolved N, P, and COD from table 18 were used in this equation to determine runoff transport from land *with* and without livestock and poultry manures surface applied. *Areas with mountains, swamps, forests, deserts, or erratic precipitation were not considered.* Tables 19, 20, and 21 show estimated runoff transport of *total* dissolved N, P, and COD, respectively, from land with agronomic surface application of livestock or poultry manures. The *increased amounts* of dissolved N, P, and COD transported in runoff from land with manures applied are shown in tables 22, 23, and 24. These *estimated increases* are assumed to be the effect of annual surface application of livestock or poultry manures. For example, the *increased* dissolved N loss from manure applied to row crop in LRA 105 without conservation farming is 2.5 lb/acre (table 22). The amount of dissolved N from land without surface applied manure would be 4.0 — 2.5 = 1.5 lb/acre. This would be the value for land receiving commercial fertilizer or manure that is incorporated into the soil.

The values in tables 25-27 have been calculated from concentrations associated with runoff occurring shortly after the manure was applied. Therefore, they tend to overestimate the effects of annual surface application of manure on transport of N, P, and COD; solubility and volatilization losses will decrease the transport potential as the manure remains exposed to the atmosphere and the soil. Tables 25-27 present short-term (4-week or snowmelt runoff) values that are closer to actual short-term field conditions.

In some LRA's, heavy seasonal rains or storms are a major runoff influence. In others, usually those north of the maximum 45 January isotherm (see fig. 6, p. 11), snowmelt transports almost all of the annual N, P, and COD transported (see table 17, p. 45, for distribution of runoff). Tables 25-27 show the total quantities of dissolved N, P, and COD transported during either the peak 4-week runoff period or by snowmelt, whichever was greater for any given LRA. The seasonal influences of runoff-transported elements on the environment may be determined by comparing the estimated peak runoff periods with the annual runoff. For example, the peak dissolved N in snowmelt runoff from row crops without conservation practices in LRA 105 is estimated to be 1.95 lb/acre (table 25). The total annual dissolved N transported is estimated to be 4.0 lb/acre (table 19). As a result, 49% (1.95 lb/acre ÷ 4.0 lb/acre = 0.49) of the estimated total annual dissolved N is transported in snowmelt runoff.

The preceding tables will assist planners in locating areas where runoff-transported nutrients are a potential problem. For LRA's not included in the tables, planners must use local climatic conditions to calculate changes in N, P, and COD transported in runoff. Procedures established within this section can be used when local conditions are known.

Percolation Quantity

Precipitation, irrigation water, and liquid manures that infiltrate the soil surface may percolate below the root zone. The amount of percolation below the root zone (usually about 4 feet) in a given area depends on climatic characteristics (precipitation and evaporation), crop grown, soil profile characteristics, and land treatment. Stewart et al. (126, 127), in Volumes I and II of Control of Water Pollution from Cropland, estimated quantities of water percolating below the 4-foot root zone in the U.S. land areas. Percolation quantities for areas with mountains, swamps, forests, or deserts were not calculated because precipitation patterns are erratic. Planners should obtain local information for specific areas from the SCS or State agricultural experiment stations.

Leaching of Nutrients

Nitrogen compounds, or other soluble chemicals not used by plants or assimilated or decomposed by micro-organisms, may leach below the 4-foot soil profile (39). Therefore, the potential for ground water pollution exists. In this manual, NO_3-N is the only ground water pollutant considered because it is the most mobile and may be a health hazard if it exceeds 10 p/m NO_3-N (45 p/m NO_3) in drinking water.

TABLE 19.—Total dissolved nitrogen transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
52	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
53	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
54	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
55	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
56	8.2	7.2	9.6	4.5	5.4	6.1	7.4
57	< 4.6	< 4.0	4.0	1.9	2.0	2.5	3.8
58	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
59	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
60	< 3.8	< 3.8	3.8	1.7	2.3	2.7	3.5
61	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
62	(2)	—	—	—	—	—	—
63	5.8	5.5	7.4	3.4	4.3	4.9	6.2
64	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
65	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
66	< 3.0	< 3.6	3.6	1.6	2.2	2.8	3.9
67	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
68	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
69	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
70	< 2.6	< 3.5	3.5	1.5	2.0	2.8	3.7
71	< 3.0	< 3.6	3.6	1.6	2.6	2.8	4.5
72	< 2.8	< 3.5	3.5	1.6	2.2	2.8	4.0
73	< 2.8	< 3.5	3.5	1.6	3.1	2.8	5.6
74	< 2.8	< 3.5	3.5	1.5	4.1	2.8	7.3
75	< 3.0	< 3.6	3.6	1.6	4.2	2.8	7.3
76	13.8	17.5	20.4	9.1	10.2	16.3	18.3
77	3.3	4.5	6.6	2.9	3.7	5.4	6.8
78	5.7	7.6	9.7	4.3	5.2	8.0	9.7
79	< 2.6	< 3.5	3.5	1.5	2.2	2.9	4.0
80	8.0	10.7	13.1	5.8	6.8	10.8	12.5
81	5.7	7.6	9.7	4.3	5.2	8.0	9.7
82	8.0	10.7	13.1	5.8	6.8	10.8	12.5
83	10.5	14.2	16.6	7.4	8.4	13.7	15.7
84	3.9	5.2	9.0	4.0	5.5	7.4	10.3
85	15.4	20.7	23.5	10.4	11.5	19.4	21.4
86	18.0	24.2	27.0	12.0	13.0	22.2	24.2
87	20.6	27.6	30.4	13.5	14.6	25.1	27.1
88	—	—	—	—	—	—	—
89	—	—	—	—	—	—	—
90	< 4.5	< 4.0	4.0	1.9	2.8	2.5	3.8
91	< 4.6	< 4.0	4.0	1.9	< 1.9	2.5	< 2.5
92	—	—	—	—	—	—	—
93	—	—	—	—	—	—	—
94	—	—	—	—	—	—	—
95	< 4.2	< 3.9	3.9	1.8	4.2	2.6	6.0
96	< 2.6	< 3.5	< 3.5	< 1.5	< 1.5	< 2.9	< 2.9
97	< 3.8	< 3.8	3.8	1.7	4.5	2.7	6.9
98	< 3.8	< 3.8	3.8	1.7	4.4	2.7	6.7
99	13.5	13.6	16.3	7.5	8.5	11.4	13.0
100	< 3.2	< 3.6	3.6	1.6	4.1	2.8	6.9
101	< 3.6	< 3.7	3.7	1.7	3.9	2.7	6.2
102	< 4.6	< 4.0	4.0	1.9	3.4	2.5	4.6

(See footnotes at end of table.)

TABLE 19.—Total dissolved nitrogen transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
103	< 4.6	< 4.0	4.0	1.9	3.4	2.5	4.6
104	10.8	10.1	12.8	6.0	7.1	8.6	10.1
105	< 4.2	< 3.9	3.9	1.8	4.0	2.6	5.7
106	< 3.0	< 3.6	3.6	1.6	4.3	2.8	7.5
107	< 3.4	< 3.7	3.7	1.7	3.8	2.7	6.3
108	< 3.6	< 3.7	3.7	1.7	3.9	2.9	6.2
109	9.5	11.4	13.9	6.3	7.4	10.9	12.8
110	10.1	11.6	13.7	6.2	7.2	10.5	12.1
111	11.9	14.3	17.1	7.7	8.8	13.4	15.3
112	15.4	20.7	23.5	10.4	11.5	19.4	21.4
113	16.6	21.1	23.9	10.7	11.8	19.2	21.1
114	19.4	24.6	27.4	12.2	13.3	22.0	24.0
115	4.2	5.3	9.1	4.1	5.6	7.3	10.1
116	15.2	20.4	23.1	10.3	11.5	19.1	21.4
117	—	—	—	—	—	—	—
118	28.0	37.7	40.4	17.9	19.2	33.3	35.6
119	—	—	—	—	—	—	—
120	13.8	17.5	20.4	9.1	10.2	16.3	18.3
121	13.8	17.5	20.4	9.1	10.2	16.3	18.3
122	8.0	10.7	15.2	6.8	8.7	12.5	16.2
123	21.3	28.7	31.8	14.1	15.3	26.2	28.5
124	8.6	10.9	13.3	6.0	6.9	10.7	12.4
125	—	—	—	—	—	—	—
126	9.2	11.0	13.5	6.1	7.1	10.1	12.3
127	—	—	—	—	—	—	—
128 N[3]	5.9	7.9	12.1	5.4	7.2	10.0	13.4
128 S	12.1	16.2	21.8	9.7	12.0	18.0	22.2
129	14.4	19.3	24.9	11.0	13.5	20.5	25.1
130	—	—	—	—	—	—	—
131 N	22.9	30.7	33.5	14.9	16.1	27.6	29.9
131 S	40.6	54.6	57.7	25.6	26.8	47.6	49.9
132	32.9	44.2	47.3	21.0	22.2	39.0	41.3
133	10.0	13.5	18.7	8.2	10.4	15.4	19.4
134 N	17.5	23.5	26.6	11.8	13.0	21.9	24.2
134 S	30.1	40.4	43.5	19.3	20.7	35.9	38.5
135	40.6	54.6	57.7	25.6	26.8	47.6	49.9
136 N	3.9	5.2	9.0	4.0	5.5	7.4	10.3
136 S	12.1	16.2	21.8	9.7	12.0	18.0	22.2
137	< 2.5	< 3.5	3.5	1.5	4.0	2.9	7.4
138	14.4	19.3	24.9	11.0	13.5	20.5	25.1
139	6.5	7.8	10.0	4.5	5.5	7.8	9.5
140	7.8	8.2	10.4	4.8	5.8	7.5	9.2
141	11.7	11.7	14.4	6.6	7.7	10.1	11.7
142	18.7	16.4	19.2	9.0	10.3	12.2	13.9
143	—	—	—	—	—	—	—
144	< 3.8	< 3.8	3.8	1.7	2.4	2.7	3.7
145	4.8	5.4	9.4	4.3	5.9	7.2	9.9
146	18.2	16.0	19.2	9.0	10.3	12.2	13.9
147	< 3.0	< 3.6	3.6	1.6	4.2	2.8	7.3
148	9.2	11.0	13.5	6.1	7.1	10.6	12.3
149	11.1	14.0	16.8	7.5	8.6	13.5	15.5

(See footnotes at end of table.)

TABLE 19.—Total dissolved nitrogen transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
150 W	15.4	20.7	23.5	10.4	11.5	19.4	21.4
150 E	40.6	54.6	57.7	25.6	26.8	47.6	49.9
151	—	—	—	—	—	—	—
152	40.6	54.6	57.7	25.6	26.8	47.6	49.9
153	20.0	26.9	30.1	13.3	14.6	24.8	27.1
154	3.9	5.2	12.8	5.7	9.0	10.5	16.8
155	19.0	25.6	31.8	14.1	16.7	26.2	31.1
156	—	—	—	—	—	—	—

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[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

TABLE 20.—Total dissolved phosphorus transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
52	< .7	< .9	< .9	< .4	< .4	< .4	< .4
53	< .7	< .9	< .9	< .4	< .4	< .4	< .4
54	< .7	< .9	< .9	< .4	< .4	< .4	< .4
55	< .7	< .9	< .9	< .4	< .4	< .4	< .4
56	2.0	1.6	2.1	.9	1.0	.9	1.0
57	< 1.1	< .9	.9	.4	.5	.4	.5
58	< .7	< .9	< .9	< .4	< .4	< .4	< .4
59	< .7	< .9	< .9	< .4	< .4	< .4	< .4
60	< .9	< .9	.9	.4	.5	.4	.5
61	< .7	< .9	< .9	< .4	< .4	< .4	< .4
62	(2)	—	—	—	—	—	—
63	1.4	1.2	1.7	.7	.9	.7	.9
64	< .7	< .9	< .9	< .4	< .4	< .4	< .4
65	< .7	< .9	< .9	< .4	< .4	< .4	< .4
66	< .7	< .9	.9	.4	.5	.4	.5
67	< .7	< .9	< .9	< .4	< .4	< .4	< .4
68	< .7	< .9	< .9	< .4	< .4	< .4	< .4
69	< .7	< .9	< .9	< .4	< .4	< .4	< .4
70	< .7	< .9	.9	.4	.5	.4	.5
71	< .7	< .9	.9	.4	.6	.4	.6
72	< .7	< .9	.9	.4	.5	.4	.5
73	< .7	< .9	.9	.4	.7	.4	.7
74	< .7	< .9	.9	.4	1.0	.4	1.0
75	< .7	< .9	.9	.4	1.0	.4	1.0
76	3.5	4.3	5.0	2.1	2.4	2.1	2.4
77	.8	1.1	1.6	.7	.9	.7	.9
78	1.4	1.9	2.4	1.0	1.3	1.0	1.3
79	< .7	< .9	.9	.4	.5	.4	.5
80	2.0	2.7	3.3	1.4	1.6	1.4	1.6
81	1.4	1.9	2.4	1.0	1.3	1.0	1.3
82	2.0	2.7	3.3	1.4	1.6	1.4	1.6
83	2.7	3.5	4.2	1.8	2.0	1.8	2.0
84	1.0	1.3	2.3	1.0	1.3	1.0	1.3
85	3.9	5.2	5.9	2.5	2.8	2.5	2.8
86	4.5	6.1	6.8	2.9	3.1	2.9	3.1
87	5.2	6.9	7.6	3.2	3.5	3.2	3.5
88	—	—	—	—	—	—	—
89	—	—	—	—	—	—	—
90	< 1.1	< .9	.9	.4	.5	.4	.5
91	< 1.1	< .9	.9	.4	< .4	.4	< .4
92	—	—	—	—	—	—	—
93	—	—	—	—	—	—	—
94	—	—	—	—	—	—	—
95	< 1.0	< .9	.9	.4	.8	.4	.8
96	< .7	< .9	< .9	< .4	< .4	< .4	< .4
97	< .9	< .9	.9	.4	.9	.4	.9
98	< .9	< .9	.9	.4	.9	.4	.9
99	3.3	3.1	3.8	1.6	1.8	1.6	1.8
100	< .8	< .9	.9	.4	.9	.4	.9
101	< .9	< .9	.9	.4	.8	.4	.8
102	< 1.1	< .9	.9	.4	.6	.4	.6

(See footnotes at end of table.)

TABLE 20.—Total dissolved phosphorus transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
103	< 1.1	< .9	.9	.4	.7	.4	.7
104	2.7	2.3	2.9	1.2	1.4	1.1	1.4
105	< 1.0	< .9	.9	.4	.8	.4	.8
106	< .7	< .9	.9	.4	1.0	.4	1.0
107	< .8	< .9	.9	.4	.8	.4	.8
108	< .9	< .9	.9	.4	.8	.4	.8
109	2.4	2.8	3.4	1.4	1.7	1.4	1.7
110	2.5	2.8	3.3	1.4	1.6	1.4	1.6
111	3.0	3.5	4.2	1.8	2.0	1.8	2.0
112	3.9	5.2	5.9	2.5	2.8	2.5	2.8
113	4.2	5.2	5.9	2.5	2.7	2.5	2.8
114	4.9	6.0	6.8	2.9	3.1	2.9	3.1
115	1.0	1.3	2.3	1.0	1.3	1.0	1.3
116	3.8	5.1	5.8	2.5	2.8	2.5	2.8
117	—	—	—	—	—	—	—
118	7.1	9.4	10.1	4.3	4.6	4.3	4.6
119	—	—	—	—	—	—	—
120	3.5	4.3	5.0	2.1	2.4	2.1	2.4
121	3.5	4.3	5.0	2.1	2.4	2.1	2.4
122	2.0	2.7	3.8	1.6	2.1	1.6	2.1
123	5.4	7.2	8.0	3.4	3.7	3.4	3.7
124	2.2	2.7	3.3	1.4	1.6	1.4	1.6
125	—	—	—	—	—	—	—
126	2.3	2.7	3.3	1.4	1.6	1.4	1.6
127	—	—	—	—	—	—	—
128 N[3]	1.5	2.0	3.0	1.3	1.7	1.3	1.7
128 S	3.0	4.1	5.4	2.3	2.9	2.3	2.9
129	3.6	4.9	6.2	2.6	3.2	2.6	3.2
130	—	—	—	—	—	—	—
131 N	5.8	7.7	8.4	3.6	3.9	3.6	3.9
131 S	10.2	13.6	14.4	6.1	6.4	6.1	6.4
132	8.3	11.1	11.8	5.0	5.3	5.0	5.3
133	2.5	3.3	4.7	2.0	2.5	2.0	2.5
134 N	4.4	5.9	6.7	2.8	3.1	2.8	3.1
134 S	7.6	10.1	10.9	4.6	5.0	4.6	5.0
135	10.2	13.6	14.4	6.1	6.4	6.1	6.4
136 N	1.0	1.3	2.3	1.0	1.3	1.0	1.3
136 S	3.0	4.1	5.4	2.3	2.9	2.3	2.9
137	< .7	< .9	.9	.4	1.0	.4	1.0
138	3.6	4.8	6.2	2.6	3.2	2.6	3.2
139	1.6	1.9	2.4	1.0	1.2	1.0	1.2
140	1.9	1.9	2.5	1.0	1.2	1.0	1.2
141	2.9	2.7	3.3	1.4	1.6	1.4	1.6
142	4.6	3.6	4.3	1.7	2.0	1.7	2.0
143	—	—	—	—	—	—	—
144	< .9	< .9	.9	.4	.5	.4	.5
145	1.2	1.3	2.3	1.0	1.3	1.0	1.3
146	4.5	3.6	4.3	1.7	2.0	1.7	2.0
147	< .7	< .9	.9	.4	1.0	.4	1.0
148	2.3	2.7	3.3	1.4	1.6	1.4	1.6
149	2.8	3.5	4.2	1.8	2.0	1.8	2.0

(See footnotes at end of table.)

TABLE 20.—Total dissolved phosphorus transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
150 W	3.9	5.2	5.9	2.5	2.8	2.5	2.8
150 E	10.2	13.6	14.4	6.1	6.4	6.1	6.4
151	—	—	—	—	—	—	—
152	10.2	13.6	14.4	6.1	6.4	6.1	6.4
153	5.1	6.7	7.5	3.2	3.5	3.2	3.5
154	1.0	1.3	3.2	1.4	2.2	1.4	2.2
155	4.8	6.4	8.0	3.4	4.0	3.4	4.0
156	—	—	—	—	—	—	—

[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

Table 21.—Total dissolved chemical oxygen demand transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
52	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
54	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
54	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
55	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
56	130.0	77.0	103.0	60.0	72.0	60.0	72.0
57	< 72.0	< 43.0	43.0	25.0	37.0	25.0	37.0
58	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
59	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
60	< 75.0	< 40.0	40.0	23.0	29.0	23.0	29.0
61	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
62	(2)	—	—	—	—	—	—
63	103.0	58.0	79.0	45.0	57.0	45.0	57.0
64	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
65	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
66	< 77.0	< 38.0	38.0	20.0	28.0	20.0	28.0
67	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
68	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
69	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
70	< 78.0	< 37.0	37.0	19.0	25.0	19.0	25.0
71	< 77.0	< 38.0	38.0	20.0	32.0	20.0	32.0
72	< 77.0	< 37.0	37.0	20.0	27.0	20.0	27.0
73	< 77.0	< 37.0	37.0	20.0	39.0	20.0	39.0
74	< 77.0	< 37.0	37.0	20.0	51.0	20.0	51.0
75	< 77.0	< 38.0	38.0	20.0	52.0	20.0	52.0
76	386.0	187.0	216.0	114.0	127.0	114.0	127.0
77	101.0	48.0	70.0	36.0	46.0	36.0	46.0
78	171.0	81.0	103.0	53.0	65.0	53.0	65.0
79	< 78.0	< 37.0	37.0	19.0	27.0	19.0	27.0
80	241.0	114.0	139.0	72.0	84.0	72.0	84.0
81	171.0	81.0	103.0	53.0	65.0	53.0	65.0
82	241.0	114.0	139.0	72.0	84.0	72.0	84.0
83	319.0	150.0	176.0	91.0	105.0	91.0	105.0
84	117.0	55.0	95.0	49.0	68.0	49.0	68.0
85	466.0	220.0	250.0	129.0	142.0	129.0	142.0
86	544.0	257.0	286.0	148.0	162.0	148.0	162.0
87	622.0	294.0	323.0	167.0	180.0	167.0	180.0
88	—	—	—	—	—	—	—
89	—	—	—	—	—	—	—
90	< 72.0	< 43.0	43.0	25.0	37.0	25.0	37.0
91	< 72.0	< 43.0	43.0	25.0	< 25.0	25.0	< 25.0
92	—	—	—	—	—	—	—
93	—	—	—	—	—	—	—
94	—	—	—	—	—	—	—
95	< 74.0	< 42.0	42.0	24.0	55.0	24.0	55.0
96	< 78.0	< 37.0	< 37.0	< 19.0	< 19.0	< 19.0	< 19.0
97	< 75.0	< 40.0	40.0	23.0	59.0	23.0	59.0
98	< 75.0	< 40.0	40.0	23.0	56.0	23.0	56.0
99	269.0	146.0	174.0	97.0	111.0	97.0	111.0
100	< 76.0	< 39.0	39.0	21.0	52.0	21.0	52.0
101	< 75.0	< 40.0	40.0	22.0	51.0	22.0	51.0

(See footnotes at end of table.)

TABLE 21.—Total dissolved chemical oxygen demand transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
				lb/acre			
102	< 72.0	< 43.0	43.0	25.0	45.0	25.0	45.0
103	< 72.0	< 43.0	43.0	25.0	50.0	25.0	50.0
104	194.0	108.0	137.0	78.0	93.0	78.0	93.0
105	< 74.0	< 42.0	42.0	24.0	52.0	24.0	52.0
106	< 77.0	< 38.0	38.0	20.0	55.0	20.0	55.0
107	< 76.0	< 39.0	39.0	21.0	49.0	21.0	49.0
108	< 75.0	< 40.0	40.0	22.0	51.0	22.0	51.0
109	245.0	121.0	148.0	79.0	93.0	79.0	93.0
110	244.0	123.0	147.0	79.0	91.0	79.0	91.0
111	307.0	152.0	182.0	97.0	111.0	97.0	111.0
112	466.0	220.0	250.0	129.0	142.0	129.0	142.0
113	463.0	224.0	254.0	133.0	147.0	133.0	147.0
114	540.0	261.0	291.0	153.0	167.0	153.0	167.0
115	116.0	56.0	97.0	51.0	71.0	51.0	71.0
116	459.0	217.0	246.0	127.0	142.0	127.0	142.0
117	—	—	—	—	—	—	—
118	847.0	400.0	429.0	222.0	238.0	222.0	238.0
119	—	—	—	—	—	—	—
120	386.0	187.0	216.0	114.0	127.0	114.0	127.0
121	386.0	187.0	216.0	114.0	127.0	114.0	127.0
122	241.0	114.0	162.0	84.0	108.0	84.0	108.0
123	645.0	305.0	338.0	175.0	190.0	175.0	190.0
124	239.0	116.0	142.0	74.0	86.0	74.0	86.0
125	—	—	—	—	—	—	—
126	238.0	118.0	144.0	77.0	89.0	77.0	89.0
127	—	—	—	—	—	—	—
128 N[3]	179.0	84.0	128.0	67.0	89.0	67.0	89.0
128 S	365.0	173.0	231.0	120.0	148.0	120.0	148.0
129	435.0	206.0	264.0	137.0	167.0	137.0	167.0
130	—	—	—	—	—	—	—
131 N	692.0	327.0	356.0	184.0	200.0	184.0	200.0
131 S	1,228.0	580.0	613.0	317.0	332.0	317.0	332.0
132	995.0	470.0	503.0	260.0	276.0	260.0	276.0
133	303.0	143.0	198.0	103.0	129.0	103.0	129.0
134 N	529.0	250.0	283.0	146.0	162.0	146.0	162.0
134 S	909.0	429.0	462.0	239.0	257.0	239.0	257.0
135	1,228.0	580.0	613.0	317.0	332.0	317.0	332.0
136 N	117.0	55.0	95.0	49.0	68.0	49.0	68.0
136 S	365.0	173.0	231.0	120.0	148.0	120.0	148.0
137	< 78.0	< 37.0	37.0	19.0	49.0	19.0	49.0
138	435.0	206.0	264.0	137.0	167.0	137.0	167.0
139	169.0	83.0	106.0	57.0	69.0	57.0	69.0
140	165.0	88.0	111.0	62.0	75.0	62.0	75.0
141	231.0	125.0	154.0	86.0	99.0	86.0	99.0
142	297.0	176.0	206.0	120.0	137.0	120.0	137.0
143	—	—	—	—	—	—	—
144	< 75.0	< 40.0	40.0	23.0	32.0	23.0	32.0
145	114.0	58.0	100.0	54.0	75.0	54.0	75.0
146	290.0	172.0	206.0	120.0	137.0	120.0	137.0
147	< 77.0	< 38.0	38.0	20.0	52.0	20.0	52.0

(See footnotes at end of table.)

TABLE 21.—Total dissolved chemical oxygen demand transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
148	238.0	118.0	144.0	77.0	89.0	77.0	89.0
149	309.0	149.0	179.0	94.0	108.0	94.0	108.0
150 W	466.0	220.0	250.0	129.0	142.0	129.0	142.0
150 E	1,228.0	580.0	613.0	317.0	332.0	317.0	332.0
151	—	—	—	—	—	—	—
152	1,228.0	580.0	613.0	317.0	332.0	317.0	332.0
153	606.0	286.0	319.0	165.0	180.0	165.0	180.0
154	117.0	55.0	136.0	70.0	112.0	70.0	112.0
155	575.0	272.0	338.0	175.0	207.0	175.0	207.0
156	—	—	—	—	—	—	—

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[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

TABLE 22.—Increase in dissolved nitrogen transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
52	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
53	< 1.9	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
54	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
55	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
56	6.9	5.9	7.9	2.9	3.5	4.5	5.4
57	< 3.8	< 3.3	3.3	1.2	1.8	1.9	2.8
58	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
59	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
60	< 3.0	< 3.1	3.1	1.1	1.4	2.0	2.6
61	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
62	(2)	—	—	—	—	—	—
63	4.8	4.4	6.0	2.1	2.7	3.6	4.6
64	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
65	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
66	< 2.2	< 2.8	2.8	.9	1.0	2.1	3.0
67	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
68	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
69	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
70	< 1.8	< 2.7	2.7	.9	1.1	2.2	2.8
71	< 2.2	< 2.8	2.8	.9	1.5	2.1	3.4
72	< 2.0	< 2.8	2.8	.9	1.2	2.1	3.0
73	< 2.0	< 2.8	2.8	.9	1.8	2.1	4.3
74	< 2.0	< 2.8	2.8	.9	2.3	2.1	5.6
75	< 2.2	< 2.8	2.8	.9	2.4	2.1	5.5
76	10.2	13.9	16.1	5.1	5.8	12.4	13.9
77	2.4	3.6	5.2	1.6	2.0	4.1	5.2
78	4.1	6.0	7.6	2.4	2.9	6.1	7.4
79	< 1.8	< 2.7	2.7	.9	1.2	2.2	3.0
80	5.7	8.5	10.4	3.2	3.8	8.2	9.5
81	4.1	6.0	7.6	2.4	2.9	6.1	7.4
82	5.7	8.5	10.4	3.2	3.8	8.2	9.5
83	7.6	11.2	13.1	4.1	4.7	10.4	11.9
84	2.8	4.1	7.1	2.2	3.1	5.6	7.8
85	11.1	16.4	18.5	5.8	6.4	14.7	16.3
86	12.9	19.1	21.3	6.6	7.2	16.9	18.4
87	14.7	21.8	24.0	7.5	8.1	19.1	20.6
88	—	—	—	—	—	—	—
89	—	—	—	—	—	—	—
90	< 3.8	< 3.3	3.0	1.2	1.8	1.9	2.8
91	< 3.8	< 3.3	3.0	1.2	1.2	1.9	1.9
92	—	—	—	—	—	—	—
93	—	—	—	—	—	—	—
94	—	—	—	—	—	—	—
95	< 3.4	< 3.2	3.2	1.1	2.6	1.9	4.4
96	< 1.8	< 2.7	< 2.7	< .9	< .9	< 2.2	< 2.2
97	< 3.0	< 3.1	3.1	1.1	2.8	2.0	5.1
98	< 3.0	< 3.1	3.1	1.1	2.6	2.0	5.0
99	10.9	11.0	13.1	4.5	5.2	8.5	9.7
100	< 2.4	< 2.9	2.9	1.0	2.4	2.1	5.2
101	< 2.8	< 3.0	3.0	1.0	2.4	2.0	4.6
102	< 3.8	< 3.3	3 3	1.2	2.2	1.9	3.3

(See footnotes at end of table.)

TABLE 22.—Increase in dissolved nitrogen transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
				lb/acre			
103	< 3.8	< 3.3	3.3	1.2	2.4	1.9	3.7
104	8.9	8.2	10.4	3.7	4.4	6.3	7.5
105	< 3.4	< 3.2	3.2	1.1	2.5	1.9	4.2
106	< 2.2	< 2.8	2.8	.9	2.5	2.1	5.7
107	< 2.6	< 3.0	3.0	1.0	2.3	2.0	4.7
108	< 2.8	< 3.0	3.0	1.0	2.4	2.0	4.6
109	7.2	9.1	11.1	3.6	4.2	8.2	9.7
110	7.8	9.3	11.0	3.6	4.2	7.9	9.1
111	9.0	11.3	13.6	4.4	5.1	10.1	11.6
112	11.1	16.4	18.5	5.8	6.4	14.7	16.3
113	12.2	16.7	18.9	6.0	6.6	14.5	16.0
114	14.3	19.5	21.7	6.9	7.5	16.7	18.2
115	3.1	4.2	7.2	2.3	3.2	5.6	7.7
116	10.9	16.1	18.3	5.7	6.4	14.5	16.3
117	—	—	—	—	—	—	—
118	20.1	29.7	31.9	10.0	10.6	25.4	27.1
119	—	—	—	—	—	—	—
120	10.2	13.9	16.1	5.1	5.8	12.4	13.9
121	10.2	13.9	16.1	5.1	5.8	12.4	13.9
122	5.7	8.5	12.0	3.8	4.9	9.5	12.4
123	15.3	22.6	25.1	7.8	8.5	19.9	21.7
124	6.3	8.6	10.6	3.4	3.9	8.1	9.4
125	—	—	—	—	—	—	—
126	6.9	8.8	10.8	3.5	4.1	8.0	9.3
127	—	—	—	—	—	—	—
128 N[3]	4.2	6.3	9.6	3.0	4.0	7.6	10.2
128 S	8.7	12.8	17.2	5.4	6.6	13.7	16.9
129	10.3	15.3	19.6	6.1	7.5	15.6	19.1
130	—	—	—	—	—	—	—
131 N	16.4	24.3	26.5	8.3	8.9	21.0	22.8
131 S	29.1	43.1	45.5	14.2	14.9	36.2	37.9
132	23.6	34.9	37.4	11.7	12.3	29.7	31.4
133	7.2	10.6	14.7	4.6	5.8	11.7	14.7
134 N	12.5	18.5	21.0	6.6	7.2	16.7	18.4
134 S	21.6	31.9	34.4	10.7	11.5	27.3	29.3
135	29.1	43.1	45.5	14.2	14.9	36.2	37.9
136 N	2.8	4.1	7.1	2.2	3.1	5.6	7.8
136 S	8.7	12.8	17.2	5.4	6.6	13.7	16.9
137	< 1.8	< 2.7	2.7	.9	2.2	2.2	5.6
138	10.3	15.3	19.6	6.1	7.5	15.6	19.1
139	4.9	6.2	7.9	2.6	3.1	5.9	7.2
140	6.2	6.6	8.4	2.9	3.5	5.6	6.8
141	9.4	9.5	11.6	4.0	4.7	7.5	8.7
142	15.7	13.4	15.7	5.7	6.6	8.9	10.2
143	—	—	—	—	—	—	—
144	< 3.0	< 3.1	3.1	1.1	1.5	2.0	2.8
145	3.7	4.3	7.5	2.5	3.4	5.4	7.5
146	15.3	13.1	15.7	5.7	6.6	8.9	10.2
147	< 2.2	< 2.8	2.8	.9	2.4	2.1	5.5
148	6.9	8.8	10.8	3.5	4.1	8.0	9.3

(See footnotes at end of table.)

Table 22.—Increase dissolved nitrogen transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1] —Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
149	8.2	11.1	13.4	4.3	4.9	10.3	11.8
150 W	11.1	16.4	18.5	5.8	6.4	14.7	16.3
150 E	29.1	43.1	45.5	14.2	14.9	36.2	37.9
151	—	—	—	—	—	—	—
152	29.1	43.1	45.5	14.2	14.9	36.2	37.9
153	14.4	21.3	23.7	7.4	8.1	18.9	20.6
154	2.8	4.1	10.1	3.2	5.0	8.0	12.8
155	13.6	20.2	25.1	7.8	9.3	19.9	23.6
156	—	—	—	—	—	—	—

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[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

TABLE 23.—Increase in dissolved phosphorus transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
52	< .6	< .8	< .8	< .3	< .3	< .3	< .3
53	< .6	< .8	< .8	< .3	< .3	< .3	< .3
54	< .6	< .8	< .8	< .3	< .3	< .3	< .3
55	< .6	< .8	< .8	< .3	< .3	< .3	< .3
56	1.8	1.4	1.9	.6	.8	.8	.9
57	<1.0	< .8	.8	.3	.4	.3	.5
58	< .6	< .8	< .8	< .3	< .3	< .3	< .3
59	< .6	< .8	< .8	< .3	< .3	< .3	< .3
60	< .8	< .8	.8	.3	.4	.3	.4
61	< .6	< .8	.8	.3	.3	.3	.5
62	(2)	—	—	—	—	—	—
63	1.3	1.1	1.5	.5	.6	.6	.8
64	< .6	< .8	< .8	< .3	< .3	< .3	< .3
65	< .6	< .8	< .8	< .3	< .3	< .3	< .3
66	< .6	< .8	.8	.3	.4	.3	.3
67	< .6	< .8	< .8	< .3	< .3	< .3	< .3
68	< .6	< .8	< .8	< .3	< .3	< .3	< .3
69	< .6	< .8	< .8	< .3	< .3	< .3	< .3
70	< .6	< .8	.8	.3	.4	.3	.4
71	< .6	< .8	.8	.3	.4	.3	.5
72	< .6	< .8	.8	.3	.4	.3	.5
73	< .6	< .8	.8	.3	.6	.3	.6
74	< .6	< .8	.8	.3	.8	.3	.8
75	< .6	< .8	.8	.3	.7	.3	.8
76	3.0	3.9	4.5	1.6	1.8	1.9	2.1
77	.7	1.0	1.5	.5	.7	.6	.8
78	1.2	1.7	2.2	.8	.9	.9	1.1
79	< .6	< .8	.8	.3	.4	.3	.5
80	1.7	2.4	2.9	1.1	1.2	1.2	1.4
81	1.2	1.7	2.2	.8	.9	.9	1.1
82	1.7	2.4	2.9	1.1	1.2	1.2	1.4
83	2.3	3.2	3.7	1.3	1.5	1.5	1.8
84	.8	1.2	2.0	.7	1.0	.8	1.2
85	3.3	4.6	5.3	1.9	2.1	2.2	2.4
86	3.8	5.4	6.0	2.2	2.4	2.5	2.7
87	4.4	6.2	6.8	2.4	2.6	2.8	3.1
88	—	—	—	—	—	—	—
89	—	—	—	—	—	—	—
90	<1.0	< .8	.8	.3	.4	.3	.5
91	<1.0	< .8	.8	.3	< .3	.3	< .3
92	—	—	—	—	—	—	—
93	—	—	—	—	—	—	—
94	—	—	—	—	—	—	—
95	< .9	< .8	.8	.3	.6	.3	.7
96	< .6	< .8	< .8	< .3	< .3	< .3	< .3
97	< .8	< .8	.8	.3	.7	.3	.8
98	< .8	< .8	.8	.3	.7	.3	.8
99	3.0	2.8	3.4	1.2	1.3	1.4	1.5
100	< .7	< .8	.8	.3	.7	.3	.8
101	< .8	< .8	.8	.3	.6	.3	.7

(See footnotes at end of table.)

TABLE 23.—Increase in dissolved phosphorus transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1] —Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
102	<1.0	< .8	.8	.3	.5	.3	.6
103	<1.0	< .8	.8	.3	.5	.3	.6
104	2.4	2.1	2.6	.9	1.0	1.0	1.2
105	< .9	< .8	.8	.2	.6	.3	.7
106	< .6	< .8	.8	.3	.7	.3	.9
107	< .7	< .8	.8	.3	.6	.3	.7
108	< .8	< .8	.8	.3	.6	.3	.7
109	2.1	2.5	3.0	1.1	1.3	1.3	1.5
110	2.2	2.5	3.0	1.0	1.2	1.2	1.4
111	2.6	3.1	3.7	1.3	1.5	1.5	1.8
112	3.3	4.6	5.3	1.9	2.1	2.2	2.4
113	3.6	4.7	5.3	1.9	2.1	2.2	2.4
114	4.2	5.4	6.1	2.2	2.3	2.5	2.7
115	.9	1.2	2.0	.7	1.0	.8	1.2
116	3.2	4.6	5.2	1.8	2.1	2.2	2.4
117	—	—	—	—	—	—	—
118	6.0	8.4	9.0	3.2	3.5	3.8	4.0
119	—	—	—	—	—	—	—
120	3.0	3.9	4.5	1.6	1.8	1.9	2.1
121	3.0	3.9	4.5	1.6	1.8	1.9	2.1
122	1.7	2.4	3.4	1.2	1.6	1.4	1.8
123	4.6	6.4	7.1	2.6	2.8	3.0	3.2
124	1.8	2.4	3.0	1.1	1.2	1.2	1.4
125	—	—	—	—	—	—	—
126	2.0	2.4	3.0	1.0	1.2	1.2	1.4
127	—	—	—	—	—	—	—
128 N[3]	1.3	1.8	2.7	1.0	1.3	1.1	1.5
128 S	2.6	3.6	4.9	1.7	2.2	2.0	2.5
129	3.1	4.3	5.6	2.0	2.4	2.3	2.8
130	—	—	—	—	—	—	—
131 N	4.9	6.9	7.5	2.7	2.9	3.1	3.4
131 S	8.7	12.2	12.9	4.6	4.8	5.4	5.6
132	7.0	9.9	10.6	3.8	4.0	4.4	4.7
133	2.1	3.0	4.2	1.5	1.9	1.7	2.2
134 N	3.7	5.3	6.0	2.1	2.4	2.5	2.7
134 S	6.4	9.0	9.7	3.5	3.7	4.1	4.3
135	8.7	12.2	12.9	4.6	4.8	5.4	5.6
136 N	.8	1.2	2.0	.7	1.0	.8	1.2
136 S	2.6	3.6	4.9	1.7	2.2	2.0	2.5
137	< .6	< .8	.8	.3	.7	.3	.8
138	3.1	4.3	5.6	2.0	2.4	2.3	2.8
139	1.4	1.7	2.2	.8	.9	.9	1.1
140	1.7	1.7	2.2	.8	.9	.9	1.1
141	2.6	2.5	3.0	1.0	1.2	1.2	1.4
142	4.2	3.3	3.8	1.3	1.5	1.5	1.7
143	—	—	—	—	—	—	—
144	< .8	< .8	.8	.3	.4	.3	.4
145	1.0	1.2	2.0	.7	1.0	.8	1.2
146	4.1	3.2	3.8	1.3	1.5	1.5	1.7
147	< .6	< .8	.8	.3	.7	.3	.8
148	2.0	2.4	3.0	1.0	1.2	1.2	1.4

(See footnotes at end of table.)

TABLE 23.—Increase in dissolved phosphorus transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
149	2.4	3.1	3.7	1.3	1.5	1.5	1.8
150 W	3.3	4.6	5.3	1.9	2.1	2.2	2.4
150 E	8.7	12.2	12.9	4.6	4.8	5.4	5.6
151	—	—	—	—	—	—	—
152	8.7	12.2	12.9	4.6	4.8	5.4	5.6
153	4.3	6.0	6.7	2.4	2.6	2.8	3.1
154	.8	1.2	2.9	1.0	1.6	1.2	1.9
155	4.1	5.7	7.1	2.5	3.0	3.0	3.5
156	—	—	—	—	—	—	—

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[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

TABLE 24.—Increase in dissolved chemical oxygen demand transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates* [1]

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
52	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
53	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
54	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
55	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
56	110.0	69.0	92.0	30.0	36.0	30.0	36.0
57	< 61.0	< 38.0	38.0	12.0	19.0	12.0	19.0
58	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
59	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
60	< 63.0	< 36.0	36.0	10.0	13.0	10.0	13.0
61	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
62	(2)	—	—	—	—	—	—
63	87.0	52.0	71.0	21.0	27.0	21.0	27.0
64	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
65	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
66	< 65.0	< 33.0	33.0	8.0	11.0	8.0	11.0
67	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
68	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
69	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
70	< 66.0	< 32.0	32.0	7.0	8.0	7.0	8.0
71	< 65.0	< 33.0	33.0	8.0	12.0	8.0	12.0
72	< 66.0	< 33.0	33.0	7.0	10.0	7.0	10.0
73	< 66.0	< 33.0	33.0	7.0	14.0	7.0	14.0
74	< 66.0	< 33.0	33.0	7.0	18.0	7.0	18.0
75	< 65.0	< 33.0	33.0	8.0	20.0	8.0	20.0
76	329.0	164.0	190.0	41.0	46.0	41.0	46.0
77	86.0	42.0	61.0	12.0	16.0	12.0	16.0
78	146.0	71.0	90.0	18.0	22.0	18.0	22.0
79	< 66.0	< 32.0	32.0	7.0	9.0	7.0	9.0
80	206.0	100.0	122.0	25.0	29.0	25.0	29.0
81	146.0	71.0	90.0	18.0	22.0	18.0	22.0
82	206.0	100.0	122.0	25.0	29.0	25.0	29.0
83	272.0	132.0	154.0	31.0	36.0	31.0	36.0
84	100.0	48.0	84.0	17.0	23.0	17.0	23.0
85	398.0	193.0	219.0	44.0	49.0	44.0	49.0
86	465.0	225.0	251.0	51.0	55.0	51.0	55.0
87	531.0	257.0	283.0	57.0	62.0	57.0	62.0
88	—	—	—	—	—	—	—
89	—	—	—	—	—	—	—
90	< 61.0	< 38.0	38.0	12.0	19.0	12.0	19.0
91	< 61.0	< 38.0	38.0	12.0	< 12.0	12.0	< 12.0
92	—	—	—	—	—	—	—
93	—	—	—	—	—	—	—
94	—	—	—	—	—	—	—
95	< 62.0	< 37.0	37.0	11.0	26.0	11.0	26.0
96	< 66.0	< 32.0	< 32.0	< 7.0	< 7.0	< 7.0	< 7.0
97	< 63.0	< 36.0	36.0	10.0	26.0	10.0	26.0
98	< 63.0	< 36.0	36.0	10.0	25.0	10.0	25.0
99	228.0	129.0	154.0	43.0	49.0	43.0	49.0
100	< 65.0	< 34.0	34.0	8.0	21.0	8.0	21.0
101	< 64.0	< 35.0	35.0	9.0	22.0	9.0	22.0
102	< 61.0	< 38.0	38.0	12.0	22.0	12.0	22.0

(See footnotes at end of table.)

TABLE 24.—Increase in dissolved chemical oxygen demand transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
	lb/acre						
103	< 61.0	< 38.0	38.0	12.0	25.0	12.0	25.0
104	162.0	96.0	122.0	37.0	44.0	37.0	44.0
105	<162.0	< 37.0	37.0	11.0	25.0	11.0	25.0
106	< 65.0	< 33.0	33.0	8.0	21.0	8.0	21.0
107	< 64.0	< 35.0	35.0	9.0	20.0	9.0	20.0
108	< 64.0	< 35.0	35.0	9.0	22.0	9.0	22.0
109	209.0	104.0	130.0	30.0	35.0	30.0	35.0
110	207.0	109.0	129.0	31.0	36.0	31.0	36.0
111	261.0	134.0	160.0	37.0	42.0	37.0	42.0
112	398.0	193.0	219.0	44.0	49.0	44.0	49.0
113	395.0	190.0	223.0	48.0	53.0	48.0	53.0
114	461.0	229.0	256.0	55.0	60.0	55.0	60.0
115	99.0	49.0	85.0	18.0	26.0	18.0	26.0
116	392.0	190.0	215.0	44.0	49.0	44.0	49.0
117	—	—	—	—	—	—	—
118	723.0	351.0	376.0	76.0	81.0	76.0	81.0
119	—	—	—	—	—	—	—
120	329.0	164.0	190.0	41.0	46.0	41.0	46.0
121	329.0	164.0	190.0	41.0	46.0	41.0	46.0
122	206.0	100.0	142.0	29.0	37.0	29.0	37.0
123	551.0	267.0	296.0	60.0	65.0	60.0	65.0
124	204.0	102.0	125.0	27.0	31.0	27.0	31.0
125	—	—	—	—	—	—	—
126	202.0	104.0	127.0	29.0	34.0	29.0	34.0
127	—	—	—	—	—	—	—
128 N[3]	153.0	74.0	113.0	23.0	31.0	23.0	31.0
128 S	312.0	151.0	203.0	41.0	51.0	41.0	51.0
129	372.0	180.0	232.0	47.0	57.0	47.0	57.0
130	—	—	—	—	—	—	—
131 N	591.0	286.0	312.0	63.0	68.0	63.0	68.0
131 S	1,049.0	508.0	537.0	109.0	114.0	109.0	114.0
132	849.0	412.0	441.0	89.0	94.0	89.0	94.0
133	259.0	125.0	174.0	35.0	44.0	35.0	44.0
134 N	451.0	219.0	248.0	50.0	55.0	50.0	55.0
134 S	776.0	376.0	405.0	82.0	88.0	82.0	88.0
135	1,049.0	508.0	537.0	109.0	114.0	109.0	114.0
136 N	100.0	48.0	84.0	17.0	23.0	17.0	23.0
136 S	312.0	151.0	203.0	41.0	51.0	41.0	51.0
137	< 66.0	< 32.0	32.0	7.0	17.0	7.0	17.0
138	372.0	180.0	232.0	47.0	57.0	47.0	57.0
139	144.0	73.0	94.0	22.0	26.0	22.0	26.0
140	140.0	78.0	99.0	27.0	32.0	27.0	32.0
141	196.0	111.0	136.0	38.0	44.0	38.0	44.0
142	251.0	157.0	184.0	60.0	69.0	60.0	69.0
143	—	—	—	—	—	—	—
144	< 63.0	< 36.0	36.0	10.0	14.0	10.0	14.0
145	97.0	51.0	88.0	22.0	30.0	22.0	30.0
146	245.0	153.0	184.0	60.0	69.0	60.0	69.0
147	< 65.0	< 33.0	33.0	8.0	20.0	8.0	20.0

(See footnotes at end of table.)

TABLE 24.—Increase in dissolved chemical oxygen demand transported *in annual runoff from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
				lb/acre			
148	202.0	104.0	127.0	29.0	34.0	29.0	34.0
149	263.0	131.0	157.0	34.0	39.0	34.0	39.0
150 W	398.0	193.0	219.0	44.0	49.0	44.0	49.0
150 E	1,049.0	508.0	537.0	109.0	114.0	109.0	114.0
151	—	—	—	—	—	—	—
152	1,049.0	508.0	537.0	109.0	114.0	109.0	114.0
153	518.0	251.0	280.0	57.0	62.0	57.0	62.0
154	100.0	48.0	119.0	24.0	38.0	24.0	38.0
155	491.0	238.0	296.0	60.0	71.0	60.0	71.0
156	—	—	—	—	—	—	—

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[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

TABLE 25.—Total dissolved nitrogen transported *during maximum 4-week period or from annual snowmelt from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]

Land Resource Area Controlling Factor		Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
Max. 4-wk. period	Snow-melt							
		lb/acre						
	52	< 2.6	< 2.27	< 2.27	<1.11	<1.11	<1.11	<1.11
	53	< 2.6	< 2.27	< 2.27	<1.11	<1.11	<1.11	<1.11
	54	< 2.6	< 2.27	< 2.27	<1.11	<1.11	<1.11	<1.11
	55	< 2.6	< 2.27	< 2.27	<1.11	<1.11	<1.11	<1.11
	56	5.89	4.09	5.45	2.66	3.22	2.66	3.22
	57	< 3.27	< 2.27	2.27	1.11	1.66	1.11	1.66
	58	< 1.96	< 1.36	< 1.36	< .67	< .67	< .67	< .67
	59	< 2.6	< 2.27	< 2.27	<1.11	<1.11	<1.11	<1.11
60		1.03	1.38	1.47	.65	.69	1.22	1.29
61		.73	.98	1.15	.51	.58	.95	1.08
62	(2)	—	—	—	—	—	—	—
	63	3.67	2.55	3.45	1.69	2.13	1.69	2.13
	64	< .65	< .45	< .45	< .22	< .22	< .22	< .22
	65	< .65	< .45	< .45	< .22	< .22	< .22	< .22
	66	< .65	< .45	.45	.22	.31	.22	.31
	67	< .33	< .23	< .23	< .11	< .11	< .11	< .11
	68	< .33	< .23	< .23	< .11	< .11	< .11	< .11
69		1.11	1.49	1.65	.73	.81	1.37	1.50
70		1.73	2.33	2.42	1.07	1.11	2.00	2.07
71		.89	1.20	1.36	.61	.68	1.13	1.26
72		.65	.87	1.04	.46	.53	.86	.99
73		1.00	1.35	1.51	.67	.74	1.25	1.38
74		1.60	2.15	2.29	1.02	1.08	1.89	2.01
75		1.60	2.15	2.29	1.02	1.08	1.89	2.01
76		3.43	4.62	4.62	2.05	2.05	3.81	3.81
77		1.73	2.33	2.42	1.07	1.11	2.00	2.07
78		1.73	2.33	2.42	1.07	1.11	2.00	2.07
79		.35	.47	.78	.35	.48	.65	.90
80		2.54	3.42	3.47	1.54	1.57	2.87	2.91
81		2.84	3.82	3.84	1.70	1.71	3.17	3.18
82		2.27	3.05	3.13	1.39	1.42	2.58	2.64
83		5.41	7.27	7.27	3.23	3.23	6.00	6.00
84		2.41	3.24	3.35	1.48	1.53	2.76	2.85
85		6.00	8.07	8.07	3.58	3.58	6.66	6.66
86		6.00	8.07	8.07	3.58	3.58	6.66	6.66
87		6.00	8.07	8.07	3.58	3.58	6.66	6.66
88		—	—	—	—	—	—	—
89		—	—	—	—	—	—	—
	90	< 3.27	< 2.27	2.27	1.11	1.66	1.11	1.66
	91	< 3.27	< 2.27	2.27	1.11	1.11	1.11	1.11
	92	—	—	—	—	—	—	—
	93	—	—	—	—	—	—	—
	94	—	—	—	—	—	—	—
	95	< 2.62	< 1.82	1.82	.89	2.04	.80	2.04
	96	< 1.96	< 1.36	< 1.36	< .67	< .67	< .67	< .67

(See footnotes at end of table.)

TABLE 25 —Total dissolved nitrogen transported *during maximum 4-week period or from annual snowmelt from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area Controlling Factor		Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
Max. 4-wk. period	Snow-melt							
		lb/acre						
	97	< 1.96	< 1.36	1.36	.67	1.73	.67	1.73
	98	< 1.96	< 1.36	1.36	.67	1.66	.67	1.66
	99	7.07	4.91	5.86	2.86	3.26	2.86	3.26
	100	< .98	< .68	.68	.33	.83	.33	.83
	101	< 1.64	< 1.14	1.14	.55	1.28	.55	1.28
	102	< 3.27	< 2.27	2.27	1.11	2.00	1.11	2.00
	103	< 3.27	< 2.27	2.27	1.11	2.22	1.11	2.22
	104	6.81	4.73	6.00	2.93	3.46	2.93	3.46
	105	< 2.62	< 1.82	1.82	.89	1.95	.89	1.95
106		1.11	1.49	1.65	.73	.81	1.37	1.50
	107	1.31	.91	.91	.44	1.02	.44	1.02
	108	1.64	1.14	1.14	.55	1.28	.55	1.28
109		1.30	1.75	1.85	.82	.87	1.53	1.62
110		1.89	2.55	2.64	1.17	1.21	2.18	2.25
111		1.92	2.58	2.67	1.19	1.23	2.21	2.28
112		4.27	5.75	5.75	2.55	2.55	4.74	4.74
113		2.76	3.71	3.73	1.65	1.66	3.08	3.09
114		4.73	6.36	6.36	2.82	2.82	5.25	5.25
115		.87	1.16	1.33	.59	.66	1.10	1.23
116		3.65	4.91	4.93	2.19	2.19	4.07	4.08
117		—	—	—	—	—	—	—
118		7.87	10.6	10.6	4.70	4.70	8.73	8.73
119		—	—	—	—	—	—	—
120		2.92	3.93	3.96	1.76	1.78	3.27	3.30
121		3.68	4.95	4.96	2.20	2.21	4.10	4.11
122		2.27	3.05	3.16	1.40	1.45	2.61	2.70
123		4.49	6.04	6.04	2.68	2.68	4.98	4.98
124		1.92	2.58	2.67	1.19	1.23	2.21	2.28
125		—	—	—	—	—	—	—
126		1.87	2.51	2.60	1.15	1.19	2.15	2.22
127		—	—	—	—	—	—	—
128 N[3]		.89	1.20	1.36	.61	.68	1.13	1.26
128 S		4.35	5.85	5.85	2.60	2.60	4.83	4.83
129		4.35	5.85	5.85	2.60	2.60	4.83	4.83
130		—	—	—	—	—	—	—
131 N		7.28	9.78	9.78	4.34	4.34	8.07	8.07
131 S		6.11	8.22	8.22	3.65	3.65	6.78	6.78
132		3.92	5.27	5.27	2.34	2.34	4.35	4.35
133		5.52	7.42	7.42	3.29	3.29	6.12	6.12
134 N		6.11	8.22	8.22	3.65	3.65	6.78	6.78
134 S		5.22	7.02	7.02	3.11	3.11	5.79	5.79
135		8.30	11.20	11.20	4.95	4.95	9.21	9.21
136 N		.70	.95	1.11	.49	.56	.92	1.05
136 S		1.78	2.40	2.53	1.12	1.18	2.09	2.19
137		.54	.73	1.05	.47	.61	.87	1.14

(See footnotes at end of table.)

TABLE 25.—Total dissolved nitrogen transported *during maximum 4-week period or from annual snowmelt from land receiving livestock or poultry manure surface-applied at agronomic rates*[1]—Continued

Land Resource Area *Controlling Factor*		Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
Max. 4-wk. period	Snow-melt							
		lb/acre						
138		3.46	4.65	4.69	2.08	2.10	3.87	3.90
139		1.22	1.64	1.75	.77	.82	1.44	1.53
	140	3.60	2.50	3.18	1.55	1.89	1.55	1.89
	141	6.09	4.23	5.18	2.53	2.93	2.53	2.93
	142	13.40	9.32	10.90	5.32	6.10	5.32	6.10
	143	—	—	—	—	—	—	—
	144	< 1.96	< 1.36	1.36	.67	.93	.67	.93
	145	1.47	1.02	1.77	.87	1.20	.87	1.20
	146	13.10	9.09	10.9	5.32	6.10	5.32	6.10
	147	< .65	< .45	.45	.22	.58	.22	.58
148		2.06	2.76	2.84	1.26	1.29	2.34	2.40
149		2.06	2.76	2.84	1.26	1.29	2.34	2.40
150 W		4.38	5.89	5.89	2.61	2.61	4.86	4.86
150 E		4.38	5.89	5.89	2.61	2.61	4.86	4.86
151		—	—	—	—	—	—	—
152		5.81	7.82	7.82	3.47	3.47	6.45	6.45
153		3.00	4.04	4.07	1.81	1.82	3.36	3.39
154		2.08	2.80	3.18	1.41	1.58	2.63	2.94
155		7.79	10.5	10.5	4.65	4.65	8.64	8.64
156		—	—	—	—	—	—	—

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[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

TABLE 26.—Total dissolved phosphorus transported *during maximum 4-week period or from annual snowmelt from land receiving surface-applied livestock or poultry manure at agronomic rates*[1]

Land Resource Area Controlling Factor		Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
Max. 4-wk. period	Snow-melt							
		lb/acre						
	52	< .7	< .45	< .45	< .17	< .17	< .17	< .17
	53	< .7	< .45	< .45	< .17	< .17	< .17	< .17
	54	< .7	< .45	< .45	< .17	< .17	< .17	< .17
	55	< .7	< .45	< .45	< .17	< .17	< .17	< .17
	56	1.42	.82	1.09	.41	.50	.41	.50
	57	< .79	< .45	.45	.17	.26	.17	.26
	58	< .47	< .27	< .27	< .10	< .10	< .10	< .10
	59	< .7	< .45	< .45	< .17	< .17	< .17	< .17
60		.26	.35	.37	.16	.17	.16	.17
61		.18	.25	.29	.12	.14	.12	.14
62		(2)	—	—	—	—	—	—
	63	.89	.51	.69	.26	.33	.26	.33
	64	< .16	< .09	< .09	< .03	< .03	< .03	< .03
	65	< .16	< .09	< .09	< .03	< .03	< .03	< .03
	66	< .16	< .09	.09	.03	.05	.03	.05
	67	< .08	< .05	< .05	< .02	< .02	< .02	< .02
	68	< .08	< .05	< .05	< .02	< .02	< .02	< .02
69		.28	.37	.41	.18	.19	.18	.19
70		.44	.58	.60	.26	.27	.26	.27
71		.23	.30	.34	.14	.16	.14	.16
72		.16	.22	.26	.11	.13	.11	.13
73		.25	.34	.38	.16	.18	.16	.18
74		.40	.54	.57	.24	.26	.24	.26
75		.40	.54	.57	.24	.26	.24	.26
76		.87	1.15	1.15	.40	.49	.49	.49
77		.44	.58	.60	.26	.27	.26	.27
78		.44	.58	.60	.26	.27	.26	.27
79		.09	.12	.20	.08	.12	.08	.12
80		.64	.85	.87	.37	.37	.37	.37
81		.72	.95	.96	.41	.41	.41	.41
82		.57	.76	.78	.33	.34	.33	.34
83		1.36	1.82	1.82	.77	.77	.77	.77
84		.61	.81	.84	.36	.37	.36	.37
85		1.51	2.02	2.02	.86	.86	.86	.86
86		1.51	2.02	2.02	.86	.86	.86	.86
87		1.51	2.02	2.02	.86	.86	.86	.86
88		—	—	—	—	—	—	—
89		—	—	—	—	—	—	—
	90	< .79	< .45	.45	.17	.26	.17	.26
	91	< .79	< .45	.45	.17	< .17	.17	< .17
	92	—	—	—	—	—	—	—
	93	—	—	—	—	—	—	—
	94	—	—	—	—	—	—	—
	95	< .63	< .36	.36	.14	.32	.14	.32
	96	< .47	< .27	< .27	< .10	< .10	< .10	< .10

(See footnotes at end of table.)

TABLE 26.—Total dissolved phosphorus transported *during maximum 4-week period or from annual snowmelt from land receiving surface-applied livestock or poultry manure at agronomic rates*[1]—Continued

Land Resource Area *Controlling Factor* Max. 4-wk. period	 Snowmelt	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
		lb/acre						
	97	< .47	< .27	.27	.10	.27	.10	.27
	98	< .47	< .27	.27	.10	.26	.10	.26
	99	1.71	.98	1.17	.45	.51	.45	.51
	100	< .24	< .14	.14	.05	.13	.05	.13
	101	< .40	< .23	.23	.09	.20	.09	.20
	102	< .79	< .45	.45	.17	.31	.17	.31
	103	< .79	< .45	.45	.17	.35	.17	.35
	104	1.65	.95	1.20	.46	.54	.46	.54
	105	< .63	< .36	.36	.14	.30	.14	.30
106		.28	.37	.41	.18	.19	.18	.19
	107	< .32	< .18	.18	.07	.16	.07	.16
	108	< .40	< .23	.23	.09	.20	.09	.20
109		.33	.44	.46	.20	.21	.20	.21
110		.48	.64	.66	.28	.29	.28	.29
111		.48	.65	.67	.28	.29	.28	.29
112		1.08	1.44	1.44	.61	.61	.61	61
113		.70	.93	.93	.40	.40	.40	.40
114		1.19	1.59	1.59	.68	.68	.68	.68
115		.22	.29	.33	.14	.16	.14	.16
116		.92	1.23	1.23	.52	.53	.52	.53
117		—	—	—	—	—	—	—
118		1.98	2.65	2.65	1.12	1.12	1.12	1.12
119		—	—	—	—	—	—	—
120		.74	.98	.99	.42	.43	.42	.43
121		.93	1.24	1.24	.53	.53	.53	.53
122		.57	.76	.79	.34	.35	.34	.35
123		1.13	1.51	1.51	.64	.64	.64	.64
124		.48	.65	.67	.28	.29	.28	.29
125		—	—	—	—	—	—	—
12		.47	.63	.65	.28	.29	.28	.29
127		—	—	—	—	—	—	—
128 N[3]		.23	.30	.34	.14	.16	.14	.16
128 S		1.10	1.46	1.46	.62	.62	.62	.62
129		1.10	1.46	1.46	.62	.62	.62	.62
130		—	—	—	—	—	—	—
131 N		1.83	2.45	2.45	1.04	1.04	1.04	1.04
131 S		1.54	2.05	2.05	.87	.87	.87	.87
132		.99	1.32	1.32	.56	.56	.56	.56
133		1.39	1.85	1.85	.79	.79	.79	.79
134 N		1.54	2.05	2.05	.87	.87	.87	.87
134 S		1.32	1.75	1.75	.75	.75	.75	.75
135		2.09	2.79	2.79	1.19	1.19	1.19	1.19
136 N		.18	.24	.28	.12	.14	.12	.14
136 S		.45	.60	.63	.27	.28	.27	.28
137		.14	.18	.26	.11	.15	.11	.15

(See footnotes at end of table.)

TABLE 26.—Total dissolved phosphorus transported *during maximum 4-week period or from annual snowmelt from land receiving surface-applied livestock or poultry manure at agronomic rates*[1]—Continued

Land Resource Area Controlling Factor		Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
Max. 4-wk. period	Snow-melt							
		lb/acre						
138		.87	1.16	1.17	.50	.50	.50	.50
139		.31	.41	.44	.19	.20	.19	.20
	140	.87	.50	.64	.24	.29	.24	.29
	141	1.47	.85	1.04	.39	.46	.39	.46
	142	3.24	1.86	2.18	.83	.95	.83	.95
	143	—	—	—	—	—	—	—
	144	< .47	< .27	.27	.10	.15	.10	.15
	145	.36	.20	.35	.13	.19	.13	.19
	146	3.16	1.82	2.18	.83	.95	.83	.95
	147	< .16	< .09	.09	.03	.09	.03	.09
148		.52	.69	.71	.30	.31	.30	.31
149		.52	.69	.71	.30	.31	.30	.31
150 W		1.10	1.47	1.47	.63	.63	.63	.63
150 E		1.10	1.47	1.47	.63	.63	.63	.63
151		—	—	—	—	—	—	—
152		1.47	1.95	1.95	.83	.83	.83	.83
153		.76	1.01	1.02	.43	.44	.43	.44
154		.52	.70	.80	.34	.38	.34	.38
155		1.96	2.62	2.62	1.11	1.11	1.11	1.11
156		—	—	—	—	—	—	—

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[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

TABLE 27.—Total dissolved chemical oxygen demand transported *during maximum 4-week period or from annual snowmelt from land receiving surface-applied livestock or poultry manure at agronomic rates*[1]

Land Resource Area Controlling Factor		Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
Max. 4-wk. period	Snow-melt							
		lb/acre						
	52	< 34	< 25	< 25	<15	<15	<15	<15
	53	< 34	< 25	< 25	<15	<15	<15	<15
	54	< 34	< 25	< 25	<15	<15	<15	<15
	55	< 34	< 25	< 25	<15	<15	<15	<15
	56	61	44	59	37	45	37	45
	57	< 34	< 25	25	15	23	15	23
	58	< 20	< 15	< 15	< 9	< 9	< 9	< 9
	59	< 34	< 25	< 25	<15	<15	<15	<15
60		31	15	16	8	9	8	9
61		22	10	12	6	7	6	7
	62	(2)	—	—	—	—	—	—
	63	38	27	37	23	30	23	30
	64	< 7	< 5	< 5	< 3	< 3	< 3	< 3
	65	< 7	< 5	< 5	< 3	< 3	< 3	< 3
	66	< 7	< 5	5	3	4	3	4
	67	< 3	< 2	< 2	< 2	< 2	< 2	< 2
	68	< 3	< 2	< 2	< 2	< 2	< 2	< 2
69		< 34	16	18	9	10	9	10
70		52	25	26	13	14	13	14
71		27	13	14	8	8	8	8
72		20	9	11	6	7	6	7
73		30	14	16	8	9	8	9
74		48	23	24	13	13	13	13
75		48	23	24	13	13	13	13
76		104	49	49	25	25	25	25
77		52	25	26	13	14	13	14
78		52	25	26	13	14	13	14
79		11	5	8	4	6	4	6
80		77	36	37	19	19	19	19
81		86	41	41	21	21	21	21
82		69	32	33	17	18	17	18
83		164	77	77	40	40	40	40
84		73	34	36	18	19	18	19
85		182	86	86	44	44	44	44
86		182	86	86	44	44	44	44
87		182	86	86	44	44	44	44
	88	—	—	—	—	—	—	—
	89	—	—	—	—	—	—	—
	90	< 34	< 25	25	15	23	15	23
	91	< 34	< 25	25	15	<15	15	<15
	92	—	—	—	—	—	—	—
	93	—	—	—	—	—	—	—
	94	—	—	—	—	—	—	—
	95	< 27	< 20	20	12	28	12	28
	96	< 20	< 15	< 15	< 9	< 9	< 9	< 9

(See footnotes at end of table.)

TABLE 27.—Total dissolved chemical oxygen demand transported *during maximum 4-week period or from annual snowmelt from land receiving surface-applied livestock or poultry manure at agronomic rates*[1]—Continued

Land Resource Area Controlling Factor: Max. 4-wk. period	Land Resource Area Controlling Factor: Snow-melt	Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
		lb/acre						
	97	< 20	< 15	15	9	24	9	24
	98	< 20	< 15	15	9	23	9	23
	99	73	53	63	40	45	40	45
	100	< 10	< 7	7	5	12	5	12
	101	< 17	< 12	12	8	18	8	18
	102	< 34	< 25	25	15	28	15	28
	103	< 34	< 25	25	15	31	15	31
	104	70	51	65	41	48	41	48
	105	< 27	< 20	20	12	27	12	27
106		34	16	18	9	10	9	10
	107	13	10	10	6	14	6	14
	108	17	12	12	8	18	8	18
109		39	19	20	10	11	10	11
110		57	27	28	15	15	15	15
111		58	27	28	15	15	15	15
112		129	61	61	32	32	32	32
113		83	39	40	21	21	21	21
114		143	68	68	35	35	35	35
115		26	12	14	7	8	7	8
116		110	52	52	27	27	27	27
117		—	—	—	—	—	—	—
118		238	112	112	58	58	58	58
119		—	—	—	—	—	—	—
120		88	42	42	22	22	22	22
121		111	53	53	27	27	27	27
122		69	32	34	17	18	17	18
123		136	64	64	33	33	33	33
124		58	27	28	15	15	15	15
125		—	—	—	—	—	—	—
126		56	27	28	14	15	14	15
127		—	—	—	—	—	—	—
128 N[3]		27	13	14	8	8	8	8
128 S		132	62	62	32	32	32	32
129		132	62	62	32	32	32	32
130		—	—	—	—	—	—	—
131 N		220	104	104	54	54	54	54
131 S		185	87	87	45	45	45	45
132		119	56	56	29	29	29	29
133		167	79	79	41	41	41	41
134 N		185	87	87	45	45	45	45
134 S		158	75	75	39	39	39	39
135		251	119	119	61	61	61	61
136 N		21	10	12	6	7	6	7
136 S		54	25	27	14	15	14	15
137		16	8	11	6	8	6	8

(See footnotes at end of table.)

TABLE 27.—Total dissolved chemical oxygen demand transported *during maximum 4-week period or from annual snowmelt from land receiving surface-applied livestock or poultry manure at agronomic rates*[1]—Continued

Land Resource Area Controlling Factor		Grass	*Small grain* with or without conservation		*Row crop* with or without conservation		*Rough plow* with or without conservation	
Max. 4-wk. period	Snow-melt							
		lb/acre						
138		105	49	50	26	26	26	26
139		37	17	19	10	10	10	10
	140	37	27	34	22	26	22	26
	141	63	46	56	35	41	35	41
	142	138	101	118	74	85	74	85
	143	—	—	—	—	—	—	—
	144	< 20	< 15	15	9	13	9	13
	145	15	11	19	12	17	12	17
	146	135	98	118	74	85	74	85
	147	< 7	< 5	5	3	8	3	8
148		62	29	30	16	16	16	16
149		62	29	30	16	16	16	16
150 W		133	63	63	32	32	32	32
150 E		133	63	63	32	32	32	32
151		—	—	—	—	—	—	—
152		176	83	83	43	43	43	43
153		91	43	43	22	23	22	23
154		63	30	34	17	20	17	20
155		236	111	111	58	58	58	58
156		—	—	—	—	—	—	—

[1] Values estimated from tables 17 and 18.

[2] It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

[3] North, N; South, S; East, E; West, W, respectively, within Land Resource Areas.

Although not considered in this manual, salt is a potential ground water pollutant, especially in irrigated areas. Care should be exercised when applying manures in irrigated areas and sections of the Southeast with salt-leaching problems. In the Southeast, leaching of plant nutrients below the 4-foot zone occurs primarily from November through April. Nutrients contained in livestock and poultry manures applied during these months would be available for leaching. Cool-season crops can provide ground cover and reduce nutrient leaching during the winter ground water recharge period. The quantity of N leached is a function of the water percolating below the 4-foot root zone and the portion of the total soluble N in the soil not used by crops.

Nitrogen leaching losses attributable to one-time, surface-applied manures are assumed negligible because surface application results in slower decomposition and nitrification rates and higher volatilization losses (168, 169). Planners should refer to procedures established by Stewart et al. (126, 127) for other leaching losses. Estimated potential N leaching losses shown in table 28 are from land with manures incorporated into the soil at rates equaling or exceeding those required to fill N requirements of crops. The equation used to calculate potential leaching losses is shown in the Appendix.

Nitrogen leaching losses may be excessive when manure application exceeds agronomic loading rates as shown in table 28. To avoid pollution of ground

TABLE 28.—*Potential increase in nitrogen leaching loss per 100 pounds of nitrogen content of crops receiving soil-incorporated livestock or poultry manure or other nitrogen source*

Land Resource Area	Manure rate [1]			
	1	2	4	6
	Potential N leaching loss			
	Lb N/100 lb crop content			
Fall-Applied Manure				
52–64, 66–78, 80–83, 84*, 85*, 86*, 87*, 90, 95*, 99, 102–106, 107*, 108*, 109, 111*, 118*, 124*, 140*, 141, 142, 146, 150*	2	5	15	25
65, 79, 97, 98, 100, 101, 110, 112, 113*, 114*, 115*, 121, 126*, 148, 149	7	20	60	100
91, 96, 123, 131, 132, 134, 135, 139, 144*, 145, 147*, 152, 153*	13	40	120	200
116, 120, 122, 128, 129, 133, 136, 137, 138, 154, 155	20	60	180	300
Spring-Applied Manure				
52–64, 66–78, 80–85, 86*, 90, 95, 97–115, 118, 120*, 121–124, 126, 128, 129, 131, 132, 133*, 134, 135, 136, 140, 141, 142, 144*, 146–149, 152*, 153*	0	0	0	0
65, 79, 87, 96, 116, 139, 145, 150	2	5	15	25
91*, 133, 138	7	20	60	100
137, 154, 155	13	40	120	200

[1] Manure or N rate: 1 = agronomic application rate to fulfill crop N requirements.
2 = twice agronomic rate, etc.

* Check figure 35, Stewart et al. (126) for exact location within LRA. Potential leaching loss for parts of this LRA may be more severe than indicated here. Always check local conditions and use local data when possible. It is not possible to estimate values for mountain, swamp, and forest regions or those with erratic climate.

water, it is essential to use recommended manure application rates. If recommended rates are not used, economic losses incurred through loss of nutrients will become more significant as fertilizer costs increase.

Worksheet 4 Instructions

Worksheet 4 summarizes the effects of livestock and poultry manure on the application site. No attempt is made to make evaluation decisions since standards and environmental quality criteria are not available for each Land Resource Area. Readers following Sample Problem 2 should refer to the problem statement and completed Worksheets 1, 2, and 3, pages 15, 16, 23, and 35, respectively.

Steps 1 through 10 below correspond to Steps 1 through 10 on Worksheet 4:

1. Use figure 4, page 8, to determine the Land Resource Area of the livestock or poultry operation.
2. Planners provide local information.
   - 2a. Check the most applicable land use for the surrounding area. If the surrounding area is other than agricultural or if future plans are for other than agricultural purposes, methods of manure application to avoid nuisance problems should be considered.
   - 2b. Draw a map of the land application site, showing features such as neighboring farms, streams, lakes, prevailing wind, cities, etc. (See fig. 10, p. 26, for an example map.) Steps 2b.1 through 2b.4 on the worksheet may be completed when the map is available.
   - 2c. Obtain present and planned zoning regulations from local offices. These regulations may have a significant effect on use

of the site for application of livestock or poultry manure.

3. Check whether the livestock or poultry manure is surface-applied or incorporated into the soil by knifing, plowing, or other tillage methods. Runoff and leaching will be affected by application method. (See Section 4, pages 25-28, for detailed information on application methods.)
4. Check the type of cropping system used on the application site.
5. Check the appropriate blank for conservation practices.
6. The quantity of runoff water from the application site will be determined in Steps 6a through 6e.
   - 6a. Use table 17, pages 45-47, to determine the quantity of runoff from land *without* manure applied. Find the appropriate Land Resource Area and type of cropping system (grass, small grain, row crop, or plowed field). Record the inches of annual runoff on line 6a.
   - 6b. Use table 17 to determine the amount of annual runoff that is contributed by snowmelt. Record the *percent by snowmelt* on Line 5b.
   - 6c. The percent of annual runoff due to rainfall may be calculated by subtracting the percent by snowmelt (Line 6b) from 100. Record the difference on Line 6c.
   - 6d. The application site area was determined on Worksheet 3. Record the area (Line 6b, Worksheet 3) on Line 6d of Worksheet 4.
   - 6e. The annual runoff from the application site may be determined with information recorded on Lines 3, 4, 5, and 6a through 6d.
     - 6e.1. Calculate the amount of snowmelt runoff and rainfall runoff. Transfer the annual runoff recorded on Line 6a, *percent by snowmelt* recorded on Line 6b, percent by rainfall recorded on Line 6c, and the application area recorded on Line 6d to appropriate lines in 6e.1 and 6e.2. By performing the calculations shown under Line 6e.1, the quantity of snowmelt and rainfall runoff from land *with manure surface-applied* may be calculated. (Note the use of the constants 0.8 and 0.95 in the calculations to reflect the reduction in runoff when manure is surface applied.)
     - 6e.2. Snowmelt and rainfall runoff with manure soil-incorporated may be calculated as shown on Line 6e.2. (Runoff from land *without manure* and land *with manure soil-incorporated* are assumed the same. However, small reductions in runoff are evident on soil with annual applications of manure.)

       Note:

       The total quantity of runoff from land with livestock or poultry manure soil-incorporated and surface-applied may be compared, using the total runoff values on Lines 6e.1 and 6e.2.
7. Check the type of cropping system used where livestock or poultry manure is applied (see Line 4). Runoff and runoff-transported nutrients will be affected by the type of crop grown or the condition of the field.
   - 7a. Estimated N transported in runoff from land with surface-applied manure may be obtained by following Steps 7a.1 through 7a.5.
     - 7a.1. The amount of N transported in runoff *annually* may be obtained by referring to table 19, page 50. Locate the LRA recorded on Line 1. The amount of N transported from land *with manure applied* is listed on table 19. The planner must select the appropriate cropping system (recorded on Line 4) and record a value on Line 7a.1. Values are listed for land both with and without conservation practices.
     - 7a.2. The quantity of N transported *due to livestock or poultry manure applied to the land* may be obtained from table 22, page 60. The planner must select the appropriate number to record on Line 7a.2.
     - 7a.3. Since runoff is dependent on precipitation patterns and snowmelt, most of the N will be transported during seasons characteristics to the climatic conditions of the LRA. Ta-

ble 25, page 68, may be used to obtain the maximum short-term amount of N transported either by rainfall or snowmelt (values for each type of cropping system listed, with or without conservation practices). Record the value on Line 7a.3.

7a.4. Make a checkmark by snowmelt or rainfall, whichever controls the maximum short-term runoff (referring to table 25).

7a.5. Total N transported annually from the application site may be calculated by multiplying the N (lb/acre) transported annually (Line 7a.1) times the application site area (Line 6d) and recording the value on Line 7a.5.

CAUTION: Values for transportation are for discharge N at field edge only.

7b. Nitrogen transported in runoff from land with soil-incorporated manure may be obtained by following Steps 7b.1 and 7b.2.

7b.1. Enter the runoff-transported N annually from Line 7a.1 and the increase in runoff-transported N due to application of manure in appropriate blanks of Line 7b.1. By subtraction, the amount of N transported from land with soil-incorporated manure should be recorded on Line 7b.1.

7b.2. The estimated amount of N transported annually from the application site with manure soil-incorporated may be calculated by multiplying the N transported annually (Line 7b.1) times the application site area (Line 6d) and recording the value on Line 7b.2.

8. The P transported in runoff may be estimated by following procedures in 7a.1 through 7b.2 and using table 19, page 50, for P transported annually from surface-applied manure, table 23, page 62, for the increase due to manure application, and table 26, page 71, for the maximum short-term, runoff-transported P. Record values on Lines 8a.1 through 8b.2.

9. The COD (indicator for organic matter transport) in runoff may be estimated by following procedures in 7a.1 through 7b.2 and using table 21, page 56, for COD transported annually, table 24, page 65, for the increase in COD transported annually, and table 27, page 74, for the maximum short-term, runoff COD. Record values on Lines 9a.1 through 9b.2.

10. Percolation of N below the root zone may be determined by completing Steps 10a through 10d.

10a and 10b. See page 49 for additional information.

10c. Potential leaching of N due to manure application at rates exceeding crop N requirements will differ depending upon the time of application. Potential N leaching from fall- and spring-applied manure at *twice* agronomic application rates may be determined by completing Steps 10c.1 through 10d.2.

10c.1. The potential N leached is obtained by use of the equation shown. Obtain the N leached from table 28, page 77, under *fall application* and record the value in the equation on Line 10c.1. Transfer the *crop content of N* from Line 2a, Worksheet 3, into the equation. Complete the answer on Line 10c.1.

10c.2. The total N leaching potential from the manure application site when manure is fall-applied may be determined with the equation shown on Line 10c.2. Transfer the value for N leached from fall-applied manure from line 10c.1 and the area of the manure application site into the equation. Complete the answer on Line 10c.2.

10d. The potential N leached when manure is *spring-applied* may be obtained by using the same procedures as Steps 10c.1 through 10c.2 and table 28, page 77, for *spring-applied* manure.

Worksheet 5 Instructions

Record the results obtained from Worksheets 2 through 4 on this worksheet for a concise summary.

SAMPLE PROBLEM 2

WORKSHEET 4. Environmental Effects of Manure on Application Site

1. Location (Land Resource Area, Fig. 4, page 8)............ 95

2. Application Site

2a Land use (surrounding area) .... [✓ Agricultural] ____ Recreation ____ Urban Development

2b Map of area .... ____ Yes [✓ No]

2b.1 Distance from waterways, lake, streams.......... NA miles

2b.2 Distance from neighbors, city, etc.............. NA miles

2b.3 Will prevailing winds cause an odor nuisance?... ____ Yes [✓ No]

2b.4 Are wells on the application site used by animals or humans? .... ____ Yes [✓ No]

2c Zoning requirements .... ____ Yes [✓ No]

3. Method of application.................................... [✓ Surface applied] ____ Soil incorporated

4. Cropping system(s) used.................................. ____ Grass ____ Small grain [✓ Row] ____ Plowed field

5. Are conservation practices used or planned? .... ____ Yes [✓ No] ____ Unknown

6. Quantity of runoff from application site (without manure applied)

6a Annual runoff (Table 17, p. 45)...................... 2.3 inches

6b Percent by snowmelt (Table 17, p. 45)................ 40 percent

6c Percent by rainfall = 100% - snowmelt% .... 60 percent

6d Application site area (Line 6b, Worksheet 3)........ 21.8 acres

6e Annual runoff from application site:

6e.1 Surface applied

Snowmelt runoff = annual runoff (inches) x fraction by snowmelt x application site (acres)

= 2.3 x 0.4 x 21.8 x (0.8) = 16.0 acre-in

Note constants 0.8 and 0.95

Rainfall runoff = annual runoff (inches) x fraction by rainfall x application site (acres)

= 2.3 x 0.6 x 21.8 x (.95) = 28.6 acre-in

Total runoff = snowmelt runoff + rainfall runoff

= 16.0 + 28.6 = 44.6 acre-in

6e.2 Soil incorporated

Snowmelt runoff = annual runoff (inches) x fraction by snowmelt x application site area (acres)

= ____ x ____ x ____ = ____ acre-in

Rainfall runoff = annual runoff (inches) x fraction by rainfall x application site area (acres)

= ____ x ____ x ____ = ____ acre-in

Total runoff = snowmelt runoff + rainfall runoff

= ____ + ____ = ____ acre-in

Sample Problem 2

Worksheet 4 (continued):

7. Estimated quantity of N transported in runoff

	Cropping System			
7a Surface-Applied Manure:	Grass	Small grain	✓ Row	Plowed field
✓ 7a.1 N transported annually (Table 19, p. 51).........	lb/acre	lb/acre	4.2 lb/acre	lb/acre
7a.2 increase due to manure (Table 22, p. 60).........	lb/acre	lb/acre	2.6 lb/acre	lb/acre
7a.3 maximum short term (Table 25, p. 68)...........	lb/acre	lb/acre	2.04 lb/acre	lb/acre

7a.4 maximum short term transport is from:(Tbl.25..... ✓ snowmelt ________ 4-week rainfall

7a.5 total N transported from application site = annual N transported (7a.1) x application site area(line 6d)

= 4.2 lb/acre x 21.8 acres = 91.6 lb/yr

7b Soil-Incorporated Manure:

7b.1 N transported annually = N transported annually w/manure applied (line 7a. 1)- increase due to manure (line 7a.2)

= ________ lb/acre - ________ lb/acre = ________ lb/acre

7b.2 Total N transported from application site = N transported annually (line 7b.1) x application site area (line 6d)

________ lb/acre x ________ acres = ________ lb/yr

8. Estimated quantity of P transported in runoff

	Cropping System			
✓ 8a Surface-Applied Manure:	Grass	Small grain	✓ Row	Plowed field
8a.1 P transported annually (Table 20, p. 54).....	lb/acre	lb/acre	0.8 lb/acre	lb/acre
8a.2 increase due to manure (Table 23, p. 62).....	lb/acre	lb/acre	0.6 lb/acre	lb/acre
8a.3 maximum short term (Table 26, p. 71).........	lb/acre	lb/acre	0.32 lb/acre	lb/acre

8a.4 maximum short term transport is from:(Tbl. 26) ✓ snowmelt ________ 4-week rainfall

8a.5 total P transported from application site = annual P transported (8a.1) x application site area (line 6d)

= 0.8 lb/acre x 21.8 acres = 17.4 lb/yr

8b Soil-Incorporated Manure:

8b.1 P transported annually = P transported annually w/ manure applied (line 8a.1) - increase due to manure (line 8a.2)

= ________ lb/acre - ________ lb/acre = ________ lb/acre

8b.2 Total P transported from application site = P transported annually (line 8b.1) x application site area (line 6d)

= ________ lb/acre x ________ acres = ________ lb/yr

SAMPLE PROBLEM 2

Worksheet 4 (continued).

9. Estimated quantity of COD transported in runoff

	Cropping System			
9a Surface-Applied Manure:	____ Grass	____ Small grain	✓ Row	____ Plowed field
9a.1 COD transported annually (Table 21, p. 56).	____ lb/acre	____ lb/acre	55 lb/acre	____ lb/acre
9a.2 increase due to manure (Table 24, p. 65)..	____ lb/acre	____ lb/acre	26 lb/acre	____ lb/acre
9a.3 maximum short term (Table 27, p. 74).....	____ lb/acre	____ lb/acre	28 lb/acre	____ lb/acre

9a.4 maximum short term transport is from:(Tbl. 27) ✓ snowmelt ____ 4-week rainfall

9a.5 total COD transport from application site = annual COD transport (9a.1) x application site area(line 6d)

= 55 lb/acre x 21.8 acres = 1199 lb/yr

9b Soil-Incorporated Manure:

9b.1 COD transported annually = COD transported annually w/man. applied (9a.1) - increase due to manure (9a.2)

= ____ lb/acre - ____ lb/acre = ____ lb/acre

9b.2 Total COD transported from application site = COD transported annually (9b.1) x application site area (line 6d)

= ____ lb/acre x ____ lb/acre = ____ lb/yr

10. Percolation below the 4 foot soil profile (potential)

✓ 10a. Surface-applied manure (Leaching of N unchanged from land w/o manure applied)

10b. Soil-incorporated manure at agronomic land application rates (Leaching of N unchanged from land w/o manure applied)

10c. Soil-incorporated manure at twice agronomic application rates---Fall application of manure

10c.1 N leached below 4-foot soil profile

$= \text{N leached per 100 lb N crop content (Table 28, p. 77)} \times \frac{\text{N content of crop (Worksheet 3, Line 2a)}}{100}$

= ____ x ____ = ____ lb/acre

10c.2 N leached from manure application site when manure is fall applied

N leached = N leached (line 10c.1) x application site area (line 6d) =

= ____ lb/acre x ____ = ____ lb/yr

SAMPLE PROBLEM 2

Worksheet 4 (conclusion).

10d Soil-incorporated manure at twice agronomic application rates---Spring application of manure

10d.1 N leached below 4-foot soil profile

$= \text{N leached per 100 lb N crop content (Table 28, page 77)} \times \frac{\text{N content of crop (Worksheet 3, Line 2a)}}{100}$

$= \_\_\_\_\_\_\_\_ \times \frac{\_\_\_\_\_\_\_\_}{100} = \_\_\_\_\_\_\_\_$ lb/ac

10d.2 N leached from manure application site when manure is spring applied

N leached = N leached (line 10d.1) x application site area (line 6d) =

= ________ lb/acre x ________ acres = ________ lb/yr

WORKSHEET 5 Summary of Results

Manure Source	1. Available manure (Worksheet 2) quantity/year wet	dry
Stored	1056	190 tons
Runoff	160,000 gal or 5.9 acre-in	

2. Agronomic land application rate (Worksheet 3) (line 4) rate/acre wet	dry
61 tons	11 tons
1.3 in or 35,000 gal	

Manure Source	3. Supplemental fertilizer required Wrksht. 3) (line 5b) lb/acre
Stored	118
Runoff	33

4. Land application area required (Worksheet 3) (line 6b) acres
17.3
4.5
=
21.8

5. Quantity of runoff from land application site (Worksheet 4) (part 6e)

Surface applied .... 44.6 acre-in (6e.1)

Soil incorporated....... ________ acre-in (6e.2)

6. N from manure transported in runoff from land (Worksheet 4, part 7)

Surface applied........ 91.6 lb/yr (7a. 5)

Soil incorporated...... ________ lb/yr (7b. 2)

7. P from manure transported in runoff from land (Worksheet 4, part 8)

Surface applied....... 17.4 lb/yr (8a.5)

Soil incorporated..... ________ lb/yr (8b.2)

8. COD from manure transported in runoff from land (Worksheet 4, part 9)

Surface applied.............. 1199 lb/yr (9a.5)

Soil incorporated............ ________ lb/yr (9b.2)

9. Percolation of N below 4-foot root zone (Worksheet 4) (part 10)

Fall applied........... — lb/yr (10c.)

Spring applied........ — lb/yr (10d.)

Section 6

ECONOMIC CONSIDERATIONS

After planners have formulated alternative guidelines regarding technically feasible waste-handling practices and systems for reducing nonpoint pollution, each alternative should be evaluated in terms of economic costs and benefits (fig. 1, p. 4). This section provides an overview of some of the factors that need to be considered in making an economic evaluation. The principles and procedures for the evaluation will be discussed in a subsequent manual.

Two types of economic effects should be considered: (1) effects on crop and livestock producers, and (2) effects on local and regional areas and subsequent water users.

Producer Considerations

Regulations or guidelines that require changes in waste-handling practices and systems could affect producers in various ways (see table 29). New investment in equipment and facilities may be required, which could increase, or in some cases decrease, production costs. The amount and seasonality of labor might also be affected. For example, increased seasonal spreading of animal manure could displace labor from other activities, thereby decreasing total farm output, or could require hiring additional employees for part of the year.

Anticipated changes in yields of crop and pastureland resulting from different manure management systems or practices should be considered. Yields may increase or decrease. An example of reduced yields would be handling systems requiring longer manure storage periods, resulting in reduced solids and nutrient content and thereby reducing the effectiveness of the manure as a source of organic fertilizer. Use of commercial fertilizer could compensate, but production costs would increase.

Cost increases not offset by productivity increases would in turn affect producers' net income and possibly their decisions as to the kinds and amounts of crops and livestock produced. Similar decisions by a number of producers in a given area could significantly alter areawide crop and livestock production.

Guidelines imposed on a planning area will likely cause economic impacts not equally shared by all producers within the area. They may result in a financial burden for smaller producers or producers of certain types of livestock or poultry. Generally, economics associated with the purchase of new machin-

TABLE 29.—*Economic considerations for assessing alternative guidelines for nonpoint pollution control*

Producer Considerations	Other Considerations
Impacts on production inputs/costs 1. Would additional investments be necessary for machinery, equipment, and storage facilities? 2. How would the quantity, price and seasonality of labor and energy inputs be affected? 3. Would operators be able to obtain necessary capital and labor to implement proposed changes?	*Area Impacts* 1. What would be the impact on the area's economy resulting from changes in the livestock and poultry operations? 2. How would input suppliers be affected? 3. Would financing be available for investment in plant and equipment? 4. Would there be an impact on purification costs for subsequent water users? 5. Would there be an impact on social/recreational/esthetic benefits?
Impacts on productivity 1. Would the nutrient value of manure be affected? 2. Would yeilds of crop or pastureland be affected?	
Income/structural/distributional impacts 1. What would be the effect on producers net income? 2. What would be the impact on small versus large operations? 3. Would the impact be greater for certain types of livestock operations than for others? 4. Would special consideration be necessary for different size or type firms to maintain their viability?	

ery and equipment to comply with guidelines are more favorable for larger production units than for smaller ones. This puts small operations at a distinct disadvantage when considering most guidelines for nonpoint pollution abatement.

Estimation of adjustment costs for major types of livestock and poultry operations, the desired reduction in pollution per animal unit, and the size distribution of these types of operations in a particular area will assist planners in estimating the economic impact of various policy recommendations. This information provides planners with a basis for evaluating which size and type of operations in a particular area should be subject to more stringent environmental standards and whether they can sustain the additional cost and remain in business. Special consideration or exclusion for certain types and smaller operations may need to be part of nonpoint regulations and guidelines, as they are in point source regulations (23, 62, 143, 152).

Other Considerations

Decisions by a number of producers to change the amount of crops and livestock produced, and equipment, fertilizer, and other supplies purchased could affect suppliers and marketing firms in the area (see table 29, p. 85). For example, sales and incomes of suppliers of feed and other materials would be reduced if total livestock and poultry production decreases. Suppliers may have to adjust their inventory storage capacity if adoption of new manure management systems significantly change the distribution of livestock production during the year. If implementation of environmental standards causes geographical shifts in production, some suppliers' business may increase. Increases in one area, however, will likely be offset by decreases elsewhere. Similar geographical adjustments could occur with marketing firms in the area if changes in production patterns were substantial.

Nonpoint guidelines that require adopting new handling methods or altering existing practices for livestock and poultry operations could affect seasonal and total labor requirements within a planning area. The type, amount, and seasonal distribution of fuel and energy use might also be affected. This could also affect storage volume needed and location within a planning area.

There are other areawide impacts from improved water quality that are difficult to define. They include possible reductions in purification costs for subsequent water users and increases in social, recreational, and esthetic benefits. Economic evaluation of the latter items requires analysis of the wants and needs of the population within the planning area and of adjacent planning areas.

GLOSSARY OF TERMS

A

Acre-foot. The volume of water that will cover 1 acre to a depth of 1 foot.

Acre-inch. The volume of water that will cover 1 acre to a depth of 1 inch.

Aeration. The process of being supplied or impregnated with air. In a well-aerated soil, the soil air is similar in composition to the atmosphere above the soil.

Aggregation, soil. The cementing or binding together of several soil particles into a secondary unit, aggregate, or granule. Water-stable aggregates, which will not disintegrate easily, are of special importance to soil structure.

Agitated pit or holding pond. A reservoir, pit, or pond, ordinarily not stirred or aerated, but which is mixed just before emptying to suspend settled solids.

Agricultural economics. The application of economic principles to the agricultural sector of the economy, including inputs, production, and marketing and distribution.

Agronomic rate. Referring to addition of organic wastes to soils at such a rate as to benefit plant growth and help to meet the fertility requirements of the particular soil. The quantity of waste added would not tax the soils' ability to degrade and assimilate the waste nor contribute to environmental degradation.

Ammonia. The gaseous compound of nitrogen and hydrogen (NH_3) commonly known as anhydrous ammonia in the fertilizer industry.

Anaerobic decomposition. Dissolution processes of organic matter caused by bacteria and other microbes not requiring free or dissolved oxygen for metabolism but rather from substances such as carbohydrates, nitrate, or sulfate.

Antecedent moisture condition. The amount of water stored in the soil on the day of a storm. It is determined by the total rainfall accumulating during the preceding 5 days.

B

Biochemical oxygen demand (BOD). The quantity of oxgen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. A standard test used in assessing waste water strength.

C

Calcareous soil. Soil containing sufficient free calcium carbonate or magnesium carbonate to effervesce carbon dioxide visibly when treated with cold 0.1 normal hydrochloric acid.

Chemical oxygen demand (COD). A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. The COD test, like the BOD test, is used to determine the degree of pollution in an effluent.

Clay. Naturally occurring mineral crystalline material found in soils and other earthy deposits, the particles being of clay size, that is, less than 0.002 millimeter in equivalent diameter.

Claypan. A dense, compact layer in the subsoil having a much higher clay content than the overlying material from which it is separated by a sharply defined boundary; formed by downward movement of clay or by synthesis of clay in place during soil formation. Claypans are usually hard when dry, and plastic and sticky when wet. They usually impede movement of water and air, and growth of plant roots.

Climate. The total of all atmospheric or meteorological influences, principally temperature, moisture, wind, pressure, and evaporation, which combine to characterize a region and give it individuality by influencing the nature of its land forms, soils, vegetation, and land use.

Conservation practices. Any of the techniques and methods for the control of erosion and sediment resulting from land-disturbing practices.

Conservation tillage. Any tillage system that reduces loss of soil or water as compared to conventional tillage.

Crop requirement. The amount of nutrients needed per acre, regardless of their origin, to grow a specified yield of a crop plant.

D

Debris. 1. The loose material arising from the disintegration of rocks and vegetative material; transportable by streams, ice, or floods. 2. The loose, scattered material often added to manure, such as bedding, spilled feed, or soil.

Debris basin. 1. An open structure or excavation in which the reduced velocity of the stream allows silt, manure solids, or other materials to settle out and be separated from the liquid runoff. 2. A settling basin.

Deep percolation. Water that percolates below the root zone and cannot be used by plants.

Denitrification. The reduction of nitrate, with nitrogen gas evolved as an end product.

Desalinization. 1. Removal of salts from saline soils, usually by leaching. 2. The conversion of salt water to sweet water, also spelled desalination.

Digestion. Although aerobic digestion is being used, the term digestion commonly refers to the anaerobic breakdown of organic matter in water solution or suspension into simpler or more biologically stable compounds, or both. Organic matter may be decomposed to soluble organic acids or alcohols and subsequently converted to such gases as methane and carbon dioxide. Organic solid materials are never completely destroyed by bacterial action alone.

Dryland farming. Crop production in low rainfall areas without irrigation.

E

Ecology. The study of interrelationships of organisms to one another and to their environment.

Effluent. 1. Solid, liquid, or gas wastes which enter the environment as a byproduct of man's activities. 2. The discharge or outflow of water from ground or subsurface storage.

Electrical conductivity. A measure of the ease with which a sample of water or a water extract of soil conducts electricity. A high conductivity indicates a high content of salts which would impair plant growth or soil physical properties or make the water unfit for consumption.

Environment. The total external conditions that may 'act upon an organism or community to influence its development or existence.

F

Fertility, soil. The quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants when other growth factors, such as light, moisture, temperature, and the physical condition of the soil, are favorable.

Fertilizer. Any organic or inorganic material of natural or synthetic origin that is added to a soil to supply elements essential to plant growth.

Fertilizer analysis. The percentage composition of fertilizer expressed in terms of nitrogen, phosphoric acid, and potash. For example, a fertilizer with a 6-12-6 analysis contains 6% nitrogen (N), 12% available phosphoric acid (P_2O_5), and 6% water-soluble potash (K_2O). Minor elements may also be included. Recent analysis expresses the percentages in terms of the elemental fertilizer (nitrogen, phosphorus, potassium).

Fertilizer value. The potential worth of the plant nutrients that are contained in the wastes and could become available to plants when applied to the soil. A monetary value assigned to a quantity of organic wastes represents the cost of obtaining the same plant nutrients in their commercial form and in the amounts found in the waste. The worth of the waste as a fertilizer can be estimated only for given soil conditions and other pertinent factors such as land availability, time, and handling.

Field capacity. The amount of water retained in a soil or in solid waste after it had been saturated and has drained freely. In soils, also called field moisture capacity (obsolete in technical work) and is usually expressed as a percentage of the oven-dry weight of the soil. In waste management, also called moisture-holding capacity or water-holding capacity.

G

Ground water. Phreatic water or subsurface water in the zone of saturation.

H

Holding pond. A pond, pit, or reservoir usually made of earth and built to store polluted runoff.

Horizon. See soil horizon.

Humus. The dark or black carboniferous residue in the soil resulting from the decomposition of vegetable tissues of plants originally growing there. Residues similar in appearance and behavior are found in composted manure and well-digested sludges. The more nearly stable part of the organic matter in soils.

Hydrologic condition. The runoff potential of a particular cropping practice. A crop under good hydrologic conditions will have a higher infiltration rate and lower runoff potential than one under poor conditions.

Hydrologic soil groups. Classification of soils by reference to their intake rate or infiltration of water, which is influenced by texture, organic matter content, stability of the soil aggregates, and soil horizon development.

I

Infiltration. The process whereby water enters the soil through the surface.

Infiltration rate. 1. The rate at which water enters the soil or other porous material under a given condition. 2. The rate at which infiltration takes place, expressed as depth of water per unit time, usually in inches or centimeters per hour.

J

K

Knifing. A means to incorporate slurry or liquid manures into the soil. The waste is injected just behind a thin, knifelike tool that opens a narrow slit in the soil.

L

Lagoon. An inclusive term commonly given to a water impoundment in which organic wastes are stored and stabilized. Lagoons may be described by the predominant biological characteristics (aerobic, anaerobic, or facultative), by location (indoor, outdoor), by position in a series (first stage, second stage, etc.), and by the organic material accepted (sewage, sludge, manure, or other).

Land resource area. An area of land reasonably alike in its relationship to agriculture with emphasis on combinations or intensities of problems in soil and water conservation; ordinarily larger than a land resource unit and smaller than a land resource region.

Land resource region. A generalized grouping of land resource areas reflecting regional relationships to agriculture with emphasis on soil and water conservation.

Leachates. Liquids that have percolated through a soil and that contain substances in solution or suspension.

Leaching. 1. The removal of soluble constituents from soils or other material by water. 2. The removal of salts and alkali from soils by abundant irrigation combined with drainage. 3. The disposal of a liquid through a nonwatertight artificial structure, conduit, or porous material by downward or lateral drainage, or both, into the surrounding permeable soil.

Leaching fraction or requirement. The fraction of the water entering the soil that must pass through the root zone to prevent soil salinity from exceeding a specified value.

Liquid manure. A suspension of livestock manure in water, in which the concentration of manure solids is low enough so the flow characteristics of the mixture are more like those of Newtonian fluids than plastic fluids. Also, animal manures or wastes having a total solids content less than 8% (wet-weight basis).

Litter. 1. Vegetative material, such as leaves, twigs, and stems of plants, lying on the surface of the ground in an undecomposed or slightly decomposed state. 2. The bedding material used for poultry.

Loading. Addition of organic wastes to soils at such a rate as to benefit plant growth and help to meet the fertility requirements of the particular soil. The quantity of waste added would not tax the soils ability to degrade and assimilate the waste nor contribute to environmental degradation.

Loam. Soil material that contains 7 to 27% clay, 28 to 50% silt, less than 53% sand, and variable amounts of organic matter.

M

Manure. 1. The fecal and urinary defecations of livestock and poultry. Manure may often contain some spilled feed, bedding, litter, or soil. 2. Synonymous with animal waste.

Manure, collectible. Manure accumulating in animal confinements that may be brought together and transported for use elsewhere as opposed to manure voided at random in pastures and on rangeland.

Manure stack. 1. A place with an impervious floor and side walls to contain manure and bedding until it may be recycled. 2. A manure bunker.

Manure tank. A storage unit in which accumulations of manure are collected before subsequent handling or ultimate disposal. Water may be added in the tank to promote liquefaction.

Micronutrient. A chemical element necessary in only extremely small amounts (less than 1 part per million) for plant growth. "Micro" refers to the amount used rather than to its essentiality. Examples are boron, chlorine, copper, iron, manganese, and zinc.

N

Nitrate. A combined form of nitrogen with oxygen, (NO_3^-), available as a nutrient for plant uptake as a fertilizer. Nitrate does not exist alone, but commonly as salts of calcium, sodium, potassium, or ammonium in soils and soil solutions.

Nitrate reduction. The chemical or biochemical reduction of nitrate to the nitrite form.

Nitrification. The biological oxidation of ammonium to nitrite and the further oxidation of nitrite to nitrate.

Nitrogen. The gaseous, essential element for plant growth, composing about 78% of the atmosphere, which is quite inert and unavailable to most plants in that form.

Nitrogen cycle. The sequence of biochemical changes undergone by nitrogen, wherein it is used by a living organism, liberated upon the death and decomposition of the organism, and converted to its original state of oxidation.

Nutrients. 1. Elements, or compounds, essential as raw materials for organism growth and development, such as carbon, oxygen, nitrogen, phosphorus, etc. 2. The dissolved solids and gases of the water of an area.

O

Organic matter. Chemical substances of animal or vegetable origin, or more correctly, of basically carbon structures, comprising compounds consisting of hydrocarbons and their derivatives.

Oxidation ditch. A shaped ditch, usually oval, with a revolving drum-like aerator, which circulates the liquid within it and supplies air to it to reduce the organic material by aerobic microbial action.

P

Percent moisture content, (solid waste). The percentage of moisture contained in solid waste; it can be calculated on a dry or wet basis, as follows:

$$1.\quad \text{Wet} = \frac{100\ (\text{water content of sample})}{\text{dry weight of sample} + \text{water content of sample}}$$

$$2.\quad \text{Dry} = \frac{100\ (\text{water content of sample})}{\text{dry weight of sample}}$$

Percolation. The downward movement of water through soil, especially the downward flow of water in saturated or nearly saturated soil at hydraulic gradients of about 1.0 or less.

Permeability, soil. The quality of a soil horizon that enables water or air to move through it. The permeability of a soil may be limited by the presence of one nearly impermeable horizon even though the others are permeable.

pH. A numerical measure of acidity or hydrogen ion activity. Neutral is pH 7.0. All pH values below 7.0 are acid, and all above 7.0 are alkaline. See *reaction, soil.*

Phosphorus, Phosphate (PO_4^{3-}), Oxide form (P_2O_5). An essential element for plant growth found in animal manures and mineral deposits. Plants take up the element from soils in the oxidized, phosphate (PO_4^{3-}) form. Often the amount of phosphorus is indicated in the diphosphate, pentoxide form (P_2O_5) in fertilizer analysis and in fertilizer recommendations.

Pollution

Point source pollution. Pollution arising from a well-defined origin such as the runoff from a beef cattle feedlot.

Nonpoint source pollution. Pollution arising from an ill-defined and diffuse source, such as the runoff from cultivated fields, grazing lands, or urban areas.

Pollution. The presence in a body of water (or soil or air) of material in such quantities that it impairs the water's usefulness or renders it offensive to sight, taste or smell. Contamination may accompany pollution. In general, a public-health hazard is created, but, in some instances, only economy or aesthetics are involved, as when waste salt brines contaminate surface waters or when foul odors pollute the air.

Pretreatment. See waste treatment.

Q

R

Ration. The amount of feed allotted to a given animal for 24 hours. It may be fed at one time or in portions at different times during the day. Ration may also refer to the constitution of the feed, i.e., the amounts of the various parts.

Reaction, soil. The degree of acidity or alkalinity of a soil usually expressed as a pH value. Descriptive terms commonly associated with certain ranges in pH are extremely acid, less than 4.5; very strongly acid, 4.5-5.0; strongly acid, 5.1-5.5; medium acid, 5.6-6.0; slightly acid, 6.1-6.5; neutral, 6.6-7.3; mildly alkaline, 7.4-7.8; moderately alkaline, 7.9-8.4; strongly alkaline, 8.5-9.0; and very strongly alkaline, more than 9.0.

Runoff, (Hydraulics). That portion of the precipitation on a drainage area that is discharged from the area in stream channels. Types include surface runoff, ground water runoff, or seepage.

S

Salinity or saline soil. A nonsodic soil containing sufficient soluble salts to impair its productivity but not containing excessive exchangeable sodium. This name was formerly applied to any soil containing sufficient soluble salts to interfere with plant growth, commonly greater than 3,000 parts per million.

Salinity. Referring to salty quality of soil, salts composed of sodium, calcium, magnesium as chlorides, sulfates, carbonates, bicarbonates, and potassium.

Sand. 1. A soil particle between 0.05 and 2.0 millimeters in diameter. 2. Any one of five soil separates; very coarse sand, coarse sand, medium sand, and very fine sand. 3. A soil textural class. See *soil texture*.

Sediment. Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Settleable solids. 1. That matter in wastewater which will not stay in suspension during a preselected settling period, such as 1 hour, but either settles to the bottom or floats to the top. 2. In the Imhoff cone test, the volume of matter that settles to the bottom of the cone in 1 hour.

Silt. 1. A soil particle between 0.05 and 0.002 millimeter in equivalent diameter. 2. A soil textural class. See *soil texture*.

Slurry manure. Animal measures or wastes having a total solids content ranging from 8 to 20% (wet-weight basis).

Soil. The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Soil dispersion. A condition in which the soil readily forms a colloidal solution. Dispersed soils usually have low permeability and aeration. They tend to shrink, crack, and become hard on drying and to slake and become plastic on wetting.

Soil horizon. A layer of soil material approximately parallel to the land surface and differing from adjacent layers by color, structure, texture, and other properties.

Soil organic matter. The organic fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population.

Soil structure. The combination or arrangement of soil particles into larger units characterized and classified on the basis of size, shape, and degree of distinctness. A good, stable soil structure is conducive to water and air movement which promote plant growth. Such a condition resists erosion by wind and water.

Soil texture. The relative proportions of the various soil separates (sand, silt, clay) in a soil as described by classes of soil texture. The textural class names may be modified by the addition of suitable adjectives when coarse fragments are present in substantial amounts, for example, gravelly silt loam. Sand, loamy sand, and sandy loam are further subdivided on the basis of the proportions of the various sand separates present.

Soil type. A subdivision of a soil series based on surface texture.

Solid manure. Animal manures or wastes having a total solids content greater than 20% (wet-weight basis).

Swelling potential, clay. The property of dry clay to increase in volume when wetted with water. Normally, the swelling is greater the higher the adsorption capacity of the clay.

T

Tilth. The physical condition of the soil related to its ease of tillage, fitness as a seedbed, and impedance to seedling emergence and root penetration.

U

V

Volatilization. Loss of the gaseous components, here particularly the ammonium nitrogen (NH_3), from animal manures.

W

Waste-management system. The collecting, conveying, storing, and processing devices and structures used to handle and dispose of animal manures.

Waste treatment. Any of the pretreatment processes applied to animal wastes to reduce waste loads and land area requirements for disposal.

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See footnote on p. 93.

APPENDIX

Runoff Volume

Conversion constants, 0.2 gal/in-ft and 0.5 gal/in-ft, for unpaved and paved lots, respectively:

$144\ \text{in}^2/\text{ft}^2 \times 1\ \text{gal}/231\ \text{in}^3 = 0.62\ \text{gal/in-ft}^2$

$0.62\ \text{gal/in-ft}^2 \times 0.3 = 0.186$, rounded to one decimal place $0.2\ \text{gal/in-ft}^2$

$0.62\ \text{gal/in-ft}^2 \times 0.8 = 0.5\ \text{gal/in-ft}^2$

Conversion constant 27,150 gal/acre-in to convert gallons to acre-inches:

$7.48\ \text{gal/ft}^3 \times 43{,}560\ \text{ft}^2/\text{acre} \times 1\ \text{ft}/12\ \text{in} = 27{,}150\ \text{gal/acre-in}$ when you drop the insignificant digits.

Total Dry Solids Transported

Conversion constant, $8.34\ \frac{\text{lb}}{\text{gal}}$, for weight of runoff for unpaved and paved lots, respectively:

$$\frac{231\ \text{in}^3}{1\ \text{gal}} \times \frac{1\ \text{ft}^3}{1728\ \text{in}^3} \times \frac{62.4\ \text{lb}}{1\ \text{ft}^3} = 8.34\ \frac{\text{lb}}{\text{gal}}$$

Considering the low solids content, the density of the runoff can be approximated as that of water or $62.4\ \frac{\text{lb}}{\text{ft}^3}$. In Sample Problems 2 and 3, the solids concentration in the runoff is taken to be 0.1%.

Parts per Million

The calculation of the concentration of a substance, such as N in water, in parts per million (p/m) means to express the weight of the N found in a million parts of water, using the same measuring unit for both the N and water. For example, suppose runoff from a field carries 3.4 lb N per acre per year and the amount of runoff is 1 inch per acre per year. What is the concentration of N in parts per million? The Appendix sections on "Runoff Volume" and "Total Dry Solids Transported" show the constants 27,150 gal/acre-in and 8.34 lb/gal. The 1 inch of runoff from 1 acre is 1 acre-in. The calculations for the concentration of N in parts per million are as follows:

27,150 gal/acre-in x 8.34 lb/gal = 226,431 lb water/acre-in

226,431 lb ÷ 1,000,000 = 0.226431 million lb water

3.4 lb N ÷ 0.226431 million lb water = 15 lb N per 1 million lb water or N concentration = 15 p/m.

Animal Waste Equations for Nitrogen Rates

Regression equations were calculated for manures with different N concentrations, since regression of the natural logarithm (ln) of total N required (R) on the ln time (T) showed this relation fit the data well. The intercepts (A) and the slopes (B) of these equations were dependent on the percent N in the manure. Regression of A on ln percent N and regression of B on ln percent N showed that the intercepts and slopes were closely related to the percent N in the manure. The equation may be written:

$$R = AT^B$$

R = manure required to supply 100 lb N

$A = \frac{445 - 235 \ln x}{20x}$ (a constant calculated using x = the N concentration (% N) in manure. The value *20* converts to tons/acre.)

T = time in years starting with the first application

$B = -0.5057 + 0.3254 \ln x$ (a constant calculated using x = % N in the manure).

If values for soil-available N and potential N losses were known, the following equation could be used to adjust the values found in table 14 to calculate total N required:

$$N_T = N_C - N_S + N_V + N_D + N_L + N_R,$$

where N_T = total N required or crop requirement
N_C = N content of the crop,
N_S = N available in the soil,
N_V = N volatilization loss,
N_D = N denitrification loss,
N_L = N leaching loss, and
N_R = N runoff loss.

N_C is known (table 10, p. 29) and N_S can be obtained for a given soil by soil tests. Because of the N losses (denitrification, volatilization, leaching, and runoff), the amount of manure to fulfill crop needs must be increased above the values in table 14.

Table 12, page 31, contains multiplication factors to allow for N volatilization and denitrification losses. The multiplication factors (MF) were derived using the following equation:

$$MF = \frac{1}{1 - [N_V + N_D]} ,$$

where N_V = volatilization loss at time of application
= 0.25 for surface-applied and 0.05 for soil-incorporated manure, and
N_D = denitrification constant for hydrologic soil groups
= 0, 0.1, 0.2, and 0.35 for hydrologic soil groups A, B, C, and D, respectively, for soil-incorporated manure.

Potential Nitrogen Leaching

The potential quantity of N leached (lb/acre) may be estimated by using the following equation:

$$N_L = L_P\ [(E_A)\ (MF)(R)(X)(DC)\ (1 - N_V - N_D)\ (2{,}000) - 0.67\ N_C],$$

where N_L = N leaching loss (lb/acre),
L_P = leaching percent,
E_A = excess manure application factor, i.e., 1 = manure application to meet a specific requirement or at agronomic rates; 2 = twice agronomic rates, etc.,
MF = multiplication factor (see table 12, p. 31),
R = manure required (dry weight) to supply 100 lb of N (see table 14, p. 33),
X = percent N in the manure,
DC = decay constant for the manure (see table 13, p. 32),
N_V = N volatilization coefficient (see table 11, p. 31),
N_D = denitrification coefficient (0, 0.1, 0.2, and 0.35 for hydrologic soil types A, B, C, and D, respectively; see Section 4, p. 28),
2,000 = conversion constant, and
N_C = N content of the crop (see table 10, p. 29).

TABLE 1.—*Some estimated quantities of livestock and poultry manures at the time available for land application*[1]

Management	Dairy		Beef		Swine				Sheep		Layers		Broilers		Turkeys	
					Farrow		Finish									
	Tons/animal-year										*Tons/100 bird-years*					
	wet	*dry*	*wet*	*dry*	*wet*	*dry*	*wet*	*dry*	*wet*	*dry*	*wet*	*dry*	*wet*	*dry*	*wet*	*dry*
Bedding Added																
Daily spread	16.9	3.38	6.4	1.28	—	—	1.3	0.25	1.5	0.29	—	—	—	—	—	—
Manure pack	11.3	3.38	4.3	1.28	—	—	0.8	0.25	1.0	0.29	3.8	1.15	2.0	0.78	10 2	3.06
Bunker	13.5	3.38	5.0	1.25	—	—	0.4	0.25	1.4	0.29	—	—	—	—	—	—
Compost pile	5.5	2.76	2.0	1.01	—	—	0.4	0.18	0.5	0.23	—	—	—	—	4.7	2.35
No Bedding Added																
Daily	11.6	1.74	4.8	0.72	—	—	1.0	0.19	0.8	0.16	—	—	—	—	—	—
Bunker	7.0	1.74	2.7	0.69	—	—	0.9	0.18	0.8	0.16	—	—	—	—	—	—
Pit (slurry)	10.6	1.59	4.8	0.72	5.9	0.46	2.2	0.18	1.1	0.16	5.5	0.83	0.7	0.60	—	—
(pit dry)	—	—	—	—	—	—	—	—	—	—	1.0	0.89	3.7	0.56	—	—
Compost	2.3	1.13	0.9	0.45	—	—	0.2	0.12	0.2	0.10	—	—	—	—	3.3	1.66
Holding pond[2]	5,500	1.28	2,230	0.52	1,590	0.37	600	0.14	510	0.12	—	—	—	—	—	—
Effluent[2]	3,500	0.38	1,850	0.20	1,370	0.14	460	0.05	460	0.05	—	—	—	—	—	—
Anaerobic lagoon[2]	4,850	0.98	2,080	0.38	1,530	0.28	600	0.11	480	0.09	3,060	0.56	2,076	0.38	—	—
Effluent[2]	3,480	0.29	1,800	0.15	1,320	0.11	480	0.04	410	0.04	2,520	0.21	1,800	0.15	—	—
Aerobic lagoon[2]	20,340	1.44	8,140	0.60	5,930	0.42	2,260	0.16	1,890	0.13	8,810	0.62	5,930	0.42	—	—
Effluent[2]	14,820	0.43	7,710	0.20	5,490	0.16	2,060	0.06	1,720	0.05	8,230	0.24	5,490	0.16	—	—
Unpaved Lot																
Mound	5.6	2.54	2.4	1.3	—	—	0.3	0.20	0.4	0.22	—	—	—	—	4.5	2.50
Compost	2.2	1.12	2.2	1.2	—	—	0.2	0.16	0.3	0.19	—	—	—	—	3.7	2.04
Paved Lot																
Bunker	5.6	1.64	2.5	0.62	—	—	0.50	0.09	—	—	—	—	—	—	—	—

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[1] Gilbertson et al. (40, 41).

[2] Values for wet weight are expressed in gallons per animal-year or gallons per 100 bird-years. Average animal weight as follows: Dairy and beef, 1,000 lb; swine farrow, 375 lb; swine finish, 150 lb; sheep, 100 lb; layers, 4 lb; broilers, 2 lb; and turkeys, 10 lb.

TABLE 2.—*Some estimated quantities of nutrients in livestock and poultry manures at the time available for land application*[1]

Management	N	P	K	Na	Ca	Mg	Fe	Zn	Mn	Cu	As
	lb/animal-yr										
Bedding											
Dairy	84–133	23.9	178.4	26.7	82.7	28.0	2.4	0.3	0.55	0.11	—
Beef	39– 63	19.0	66.0	8.6	15.3	7.8	2.4	0.2	0.24	0.04	—
Swine	17– 30	7.6	14.3	2.3	11.8	3.1	0.4	2.1	0.8	0.2	—
Sheep	10– 16	4.0	17.2	1.7	1.9	1.2	0.5	0.04	0.06	0.01	—
Layers[2]	69	41.0	53.0	20.1	172.0	13.9	4.0	0.9	0.8	0.3	—
Broilers[2]	57	22.5	74.1	10.5	92.4	9.8	1.8	3.5	0.3	0.06	0.3
Turkeys[2]	162–222	85.7	132.7	40.8	359.5	38.3	45.9	13.8	1.3	0.3	—
No Bedding											
Dairy	15–110	20.7	98.2	14.5	71.8	22.0	1.8	0.30	0.4	0.08	—
Beef	15– 46	18.0	39.0	4.4	11.6	5.8	2.1	0.2	0.2	0.03	—
Swine (Farrowing)	21– 54	19.5	38.0	4.9	30.0	7.7	0.9	5.4	2.2	0.4	—
(Finish)	8– 29	7.4	10.5	1.5	9.2	2.3	0.3	2.0	0.7	0.1	—
Sheep	4– 10	3.7	11.0	0.8	1.0	0.8	0.5	0.04	0.05	0.01	—
Layers[2]	24– 75	40.0	40.2	18.2	170.0	13.0	3.9	0.9	0.8	0.3	—
Broilers[2]	19– 70	21.7	25.5	9.2	91.3	9.2	1.7	3.5	0.3	0.06	0.3
Unpaved Lot											
Dairy	61– 98	—	—	—	—	—	—	—	—	—	—
Beef	30– 38	13.0	14.4	4.4	11.6	5.8	2.1	0.2	0.2	0.03	—
Swine (finish)	15– 21	6.0	7.1	1.9	11.4	2.9	0.4	2.1	0.8	0.2	—
Sheep	8– 11	3.2	7.3	0.8	1.0	0.8	0.5	0.04	0.05	0.01	—
Turkeys[2]	144–203	68.3	55.8	35.7	355.0	35.8	45.6	13.8	1.2	0.3	—

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[1] Gilbertson et al. (40, 41). The United States Census for 1974 and estimates of nutrient losses in current management systems were used to compute the values.

[2] Values for layers, broilers, and turkeys are expressed as lb/100 bird-year. Average animal weight as follows: dairy and beef, 1,000 lb; swine farrow, 375 lb; swine finish, 150 lb; sheep, 100 lb; layers, 4 lb; broilers, 2 lb; and turkeys, 10 lb.

WORKSHEET 1 Problem Evaluation

Sample Problem 3

(Spring and fall application or daily application)

1. What is the manure-management system problem?

   A county has 60 dairy farms with 100 cows in each farm. The manure is spread daily at 30 of the dairies. The other 30 spread the waste in spring and fall, and incorporate it into the soil. About 20 tons (wet weight) are spread per acre. Will this application cause a problem with NO_3-N? What is the agronomic rate?

2. What is known about the current system, i.e., location, climate, livestock or poultry type, animal numbers, etc.?

   60-100 head dairies (6,000 cows)
     30 dairies spread daily with tank wagons
     30 dairies spread in the spring and fall from manure storage (covered bunkers)
   Cold humid climate with maximum 33 inches rainfall in LRA 103;
     Estimated leaching is 7 inches, land for use of runoff can use about 6 inches of irrigation.
     Solids in runoff estimated at 0.1%.
   Soil group B (sandy or silt loam). All dairies have barns and paved lots.
     Soil can supply about 55 lb N during growing season in row crops and 5 lb N in pastures (orchardgrass, bluegrass, timothy).

3. What answers should the worksheets provide?

   Agronomic rates for corn silage and for meadow and pastureland.
   Acres of land required for manure utilization.
   Quantity of runoff and solids.
   N available from manure.
   Check for salt problems.
   Potential NO_3-N percolating with spring and fall applications.

4. With the above information completed, proceed to Worksheet 2.

Sample Problem 3

WORKSHEET 2 Determining Quantities of Livestock or Poultry Manures Available for Land Application

1. Location (LRA, Figure 4, page 8) 103
2. Climate (Figure 6, page 11) .... ✓ cold; ___ cool; ___ warm; ___ hot; ✓ humid; ___ arid;
3. Animal type.. Dairy
4. Number of animals (one-time capacity or inventory number) 100
5. Management system (Problem description)........................ Barn; paved lot; covered bunker
6. Check manure source and form and fill in the blanks below using local data for characteristics.

Manure Source and Form				Wet Quantity			Dry Weight		
Source[1] (Table 7, page 22)	Form			Wet weight or gal/ animal/[2] year	x Animal number	= Annual wet quantity	Dry weight/ animal/ year	X Animal number	= Annual dry weight[4]
	Solid	Slurry	Liquid						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Barn..............................	✓			18.5 tons	100	1850 tons	2.4	100	240 tons
Pack									
Pit									
Floor ✓									
Paved lot	✓								
Unpaved lot									
Runoff (Tables 5 and 6, pages 20 & 21; text, page 20)									
Effluent [4]......................			✓	1650 gal	100	165,000 or 6.1 acre-in	.00688	100	0.688 ton
Settled Solids [4]...........							(0.688	0.6)[4]	0.41 ton
Stored Manure.....................									
Holding pond (agitated)[3]......									
Effluent [4]									
Settled Solids [4]							(	)[4]	
Anaerobic lagoon (agitated) [3].									
Effluent [4]......................									
Settled Solids [4]...........							(	)[4]	
Aerobic lagoon (agitated) [3]...									
Effluent [4]......................									
Settled Solids [4]...........							(	)[4]	
Oxidation ditch									
Oxidation ditch overflow holding pond (agitated) ....[3]									
Effluent [4]......................									
Settled Solids [4]...........							(	)[4]	
Other									
______________..............									
______________..............									

---

[1] Include all sources and forms of manures for a particular system.

[2] Liquids are expressed in gallons per animal per year; to convert gallons to acre-inches, divide by 27,150 gal/acre-in; slurry and solids are expressed in tons/animal/year.

[3] If holding ponds or lagoons are not agitated when pumped out, or a debris basin is used to separate solids, enter wet quantity under effluent.

[4] If ponds, lagoons, etc., are not agitated, estimate dry weight effluent and settled solius as follows: Settled solids dry weight = total runoff solids times 0.6. If available, use reliable local estimates of the fraction of total runoff solids that can be expected to settle out.

Sample Problem 3

WORKSHEET 3 Determining Application Rate of Livestock or Poultry Manure to Land [1]

I. Location (LRA, Figure 4, page 8) 103

1a Topographic Features .... [✓ Flat] [✓ Rolling] ____ Steep Slope

1b Conservation Practices .... ____ Yes [✓ No] ____ Unknown

1c Hydrologic Soil Group (Section 4, page 28; Table 17, page 45) ____ A [✓ B] ____ C ____ D

1d Irrigation .... ____ Yes [✓ No]

If yes:

1d.1 Water Source .... ____ Ground water ____ Surface water

1d.2 Water Electrical Conductivity (EC) (mmhos/cm) .... ____ ____

1e Climate (Figure 6, page 11) .... [✓ cold]; ____ cool; ____ warm; ____ hot; ____ arid; [✓ humid]

Maximum (Average) Annual Precipitation (Table 6, page 21) .. 33 inches/year

1f Application time [circle most probable months] (Table 9, page 27) J F M A M J J A S O N D Daily

1g Method of application .... [✓ Surface] ____ Soil incorporate ____ Unknown

1h Type of cropping system ... pasture .... [✓ Grass] ____ Small grain ____ Row ____ Plowed field

1i Other considerations:

1i.1 Is land plowed .... ____ Yes [✓ No] ____ Unknown

1i.2 If yes, when .... ____ Spring ____ Fall ____ Unknown

2. Agronomic Application Rates

2a N content of crop[1] (Table 10, page 29) .... 60 lb/acre N mineralization on grassland low

2b N available in soil (soil test)[2] .... 5 lb/acre

2c N needed from manure

2c.1 Needed [N content of crops (line 2a) - N available in soil (line 2b)] .... 55 lb/acre

2c.2 N needed from manure (line 2c.1 divided by 2)[3] .... 55 lb/acre

2d Recommended Dry and Wet Rates (Table 7, page 22) In this case it is reasonable to apply this much manure to grassland.

Manure Source (Worksheet 2) (1)	Percent N (local analysis or Table 7, page 22) (2)	Manure needed to supply 100# N (Table 14. p. 33, or calculated vol., p. 32) (3) rate/acre	Multiplication Factor (Table 12, page 31) (4)	Recommended Dry Rate or Volume (col. 3 x col. 4 x manure N / 100) (5) rate/acre	Recommended Wet Rate (calculate from col. 5)[4] (6) rate/acre
Runoff	0.015	80,000 gal or 2.94	1.33	58,500 gal	2.2 in
Solids	3.2	in 3.6 tons (dry)	1.33	2.2 tons	17.0 tons

See footnotes at end of worksheet.

Worksheet 3 (continued).

3. Loading rate limitations

Salinity limits

Manure source (Worksheet 2)	Solids	________	Runoff
3a Manure salt content (%) or Runoff electrical conductivity (EC in mmhos/cm) (Table 7, p. 22)	11.2 %	________ %	4.7 mmhos/cm
3b Salinity calculations			3.7+1 = 4.7 6.0 X 10 = 1.3 inches 4.7 Runoff in 6" of irrigation
3b.1 Leaching required for soil for low salinity status (Text, pages 32-35)	7 inches	________ inches	
3b.2 Irrigation water to dilute runoff (Figures 15 and 16, pages 37 and 38)			4.7 inches/ 1.3 inches of runoff
3c Nonirrigated land limiting application rate (Figures 13 and 15, pages 36 and 37)	20 tons/acre (dry)	________ tons/acre (dry)	1.3 inches/acre
3d Irrigated land limiting application rate (Figures 13 and 15, pages 36 and 37)	________ tons/acre (dry)	________ tons/acre (dry)	________ inches/acre-ft irrigation

3e Crop tolerance to salinity (Table 15, page 35) ________ very high; ________ high; ________ medium; ✓ low;

Other limitations (grass tetany, fat necrosis, etc.) Explain: ________________________________

Manure Source	Solids	________	Runoff
4. The limited application rate is the lesser quantity shown on lines 2d or 3c (nonirrigated) or 3d (irrigated)	2.2 tons/acre (dry)	________ tons/acre (dry)	1.3 in/acre ________ in/acre-ft irrigation

5. Because of the limited application rate, determine the supplemental fertilizer required:

5a Actual N applied in manure: limiting application rate (lines 2d, 3c, or 3d) x 100 / adjusted app. rate (line 2d or col. 3 x col. 4) = Actual N applied

30 x 1.33 = 3.99
1.94 x 1.33 = 3.47

Manure Source	Solids	2.2	x	100 / 3.99	=	55 lb N/acre
	Runoff	1.3	x	100 / 3.47	=	37 lb N/acre
	________	________	x	100 / ________	=	________ lb N/acre

5b Supplemental N required: N needed (line 2c.1) - N applied (line 5a) = supplemental N required

Manure Source	Solids	no problem with salinity and 17 tons (wet wt.) could be applied	-	________	=	0 lb N/acre
	Runoff	55	-	37	=	18 lb N/acre
	________	________	-	________	=	________ lb N/acre

See footnotes at end of Worksheet.

(continued)

Worksheet 3. (conclusion).

6. Application area

6a Manure source (from Worksheet 2)	Available quantity (Worksheet 2)	÷	Application rate (line 4) (rate/acre)	= Area required (acres)
Solids	240 tons	÷	2.2 tons/acre (dry)	= 109 acres
Runoff	165,000 gals	÷	1.3 in/acre	= 4.7 acres
	or 6.1 acre-in	÷		=

6b Total application area (add all areas required for each manure source) = 114 acres

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[1] Nitrogen required by crops must be adjusted to correspond to expected yields and N content for the area and soils if different from Table 10.

[2] Contact County Extension and Soil Conservation Service offices for local information. Use Agriculture Handbook 296 for general information for Land Resource Areas.

[3] Assuming one-half of the N needed is to come from the manure. Any other convenient fraction could be assigned to the quantity of N to be derived from the manure source. See text, page 30 .

[4] Recommended wet weight quantities are expressed in tons of manure. To obtain gallons of manure, multiply by 240 $\left[\frac{2000\text{ lb}}{1\text{ ton}} \times \frac{1\text{ gal}}{8.34\text{ lb}} = \frac{240\text{ gal}}{1\text{ ton}}\right]$. To convert gal/acre to in/acre, divide by 27,150 gal/acre-in. To calculate wet weight from dry weight of solids, divide column 5 by the fractional dry weight.

Sample Problem 3

WORKSHEET 4. Environmental Effects of Manure on Application Site

1. Location (Land Resource Area, Fig. 4, page 8) 103
2. Application Site [✓ Agricultural] ___ Recreation ___ Urban Development
   - 2a Land use (surrounding area) .... ___ Yes [✓ No]
   - 2b. Map of area ....
     - 2b.1 Distance from waterways, lake, streams .... ___ miles
     - 2b.2 Distance from neighbors, city, etc .... ___ miles
     - 2b.3 Will prevailing winds cause an odor nuisance? ... ___ Yes ___ No
     - 2b.4 Are wells on the application site used by animals or humans? .... ___ Yes ___ No
   - 2c Zoning requirements .... ___ Yes ___ No
3. Method of application .... [✓ Surface applied] ___ Soil incorporated
4. Cropping system(s) used. pasture .... [✓ Grass] ___ Small grain ___ Row ___ Plowed field
5. Are conservation practices used or planned? .... ___ Yes ___ No ___ Unknown
6. Quantity of runoff from application site (without manure applied)
   - 6a Annual runoff (Table 17, p. 45) .... <1 inches
   - 6b Percent by snowmelt (Table 17, p. 45) .... 50 percent
   - 6c Percent by rainfall = 100% - snowmelt% .... 50 percent
   - 6d Application site area (Line 6b, Worksheet 3) .... 114 acres
   - 6e Annual runoff from application site:

6e.1 Surface applied

Snowmelt runoff = annual runoff (inches) x fraction by snowmelt x application site (acres)
= <1 x 0.5 x 114 x (0.8) = <46 acre-in

Rainfall runoff = annual runoff (inches) x fraction by rainfall x application site (acres)
= <1 x 0.5 x 114 x (.95) = <46 acre-in

Total runoff = snowmelt runoff + rainfall runoff
= <46 + <46 = <92 acre-in

6e.2 Soil incorporated

Snowmelt runoff = annual runoff (inches) x fraction by snowmelt x application site area (acres) = ___ acre-in
= ___ x ___ x ___

Rainfall runoff = annual runoff (inches) x fraction by rainfall x application site area (acres) = ___ acre-in
= ___ x ___ x ___

Total runoff = snowmelt runoff + rainfall runoff
= ___ + ___ = ___ acre-in

Worksheet 4 (continued).

7. Estimated quantity of N transported in runoff

7a **Surface-Applied Manure:**

	Cropping System			
	✓ Grass	Small grain	Row	Plowed field
7a.1 N transported annually (Table 19, p. 51)..........	< 4.6 lb/acre	lb/acre	lb/acre	lb/acre
7a.2 increase due to manure (Table 22, p. 60)..........	< 3.8 lb/acre	lb/acre	lb/acre	lb/acre
7a.3 maximum short term (Table 25, p. 68)............	< 3.27 lb/acre	lb/acre	lb/acre	lb/acre
7a. 4 maximum short term transport is from:(Tbl.25.....	✓ snowmelt		4-week rainfall	

7a. 5 total N transported from application site = annual N transported (7a.1) x application site area(line 6d)

= < 4.6 lb/acre x 114 acres = < 524 lb/yr

7b **Soil-Incorporated Manure:**

7b.1 N transported annually = N transported annually w/manure applied (line 7a. 1)- increase due to manure (line 7a.2)

= ______ lb/acre - ______ lb/acre = ______ lb/acre

7b.2 Total N transported from application site = N transported annually (line 7b.1) x application site area (line 6d)

______ lb/acre x ______ acres = ______ lb/yr

8. Estimated quantity of P transported in runoff

8a **Surface-Applied Manure:**

	Cropping System			
	✓ Grass	Small grain	Row	Plowed field
8a.1 P transported annually (Table 20, p. 54).....	< 1.1 lb/acre	lb/acre	lb/acre	lb/acre
8a.2 increase due to manure (Table 23, p. 62).....	< 1.0 lb/acre	lb/acre	lb/acre	lb/acre
8a.3 maximum short term (Table 26, p. 71)..........	< 0.79 lb/acre	lb/acre	lb/acre	lb/acre
8a.4 maximum short term transport is from:(Tbl. 26)	✓ snowmelt		4-week rainfall	

8a.5 total P transported from application site = annual P transported (8a.1) x application site area (line 6d)

= < 1.1 lb/acre x 114 acres = < 125 lb/yr

8b **Soil-Incorporated Manure:**

8b.1 P transported annually = P transported annually w/ manure applied (line 8a.1) - increase due to manure (line 8a.2)

= ______ lb/acre - ______ lb/acre = ______ lb/acre

8b.2 Total P transported from application site = P transported annually (line 8b.1) x application site area (line 6d)

= ______ lb/acre x ______ acres = ______ lb/yr

Worksheet 4 (continued).

9. Estimated quantity of COD transported in runoff

		Cropping System		
9a Surface-Applied Manure:	✓ Grass	Small grain	Row	Plowed field
9a.1 COD transported annually (Table 21, p. 56).	<72 lb/acre	lb/acre	lb/acre	lb/acre
9a.2 increase due to manure (Table 24, p. 65)..	<61 lb/acre	lb/acre	lb/acre	lb/acre
9a.3 maximum short term (Table 27, p. 74).....	<34 lb/acre	lb/acre	lb/acre	lb/acre

9a.4 maximum short term transport is from: (Tbl. 27) ✓ snowmelt ______ 4-week rainfall

9a.5 total COD transport from application site = annual COD transport (9a.1) x application site area (line 6d)

= <72 lb/acre x 114 acres = <82.08 lb/yr

9b Soil-Incorporated Manure:

9b.1 COD transported annually = COD transported annually w/man. applied (9a.1) - increase due to manure (9a.2)

= ______ lb/acre - ______ lb/acre = ______ lb/acre

9b.2 Total COD transported from application site = COD transported annually (9b.1) x application site area (line 6d)

= ______ lb/acre x ______ lb/acre = ______ lb/yr

10. Percolation below the 4 foot soil profile (potential)

10a. Surface-applied manure (Leaching of N unchanged from land w/o manure applied)

10b. Soil-incorporated manure at agronomic land application rates (Leaching of N unchanged from land w/o manure applied)

10c. Soil-incorporated manure at twice agronomic application rates---Fall application of manure

10c.1 N leached below 4-foot soil profile

$= N \text{ leached per 100 lb N crop content (Table 28, p. 77)} \times \frac{N \text{ content of crop (Worksheet 3, Line 2a)}}{100}$

= ______ x ______ = ______ lb/acre

10c.2 N leached from manure application site when manure is fall applied

N leached = N leached (line 10c.1) x application site area (line 6d) =

= ______ lb/acre x ______ = ______ lb/yr

Worksheet 4 (conclusion).

10d Soil-incorporated manure at twice agronomic application rates---Spring application of manure

10d. 1 N leached below 4-foot soil profile

$$= \text{N leached per 100 lb N crop content (Table 28, page 77)} \times \frac{\text{N content of crop (Worksheet 3, Line 2a)}}{100}$$

$$= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \times \frac{\_\_\_\_\_\_\_\_\_\_\_\_}{100} = \_\_\_\_\_\_\_\_\_\_ \text{ lb/ac}$$

10d.2 N leached from manure application site when manure is spring applied

N leached = N leached (line 10d.1) x application site area (line 6d) =

= ____________ lb/acre x ________________ acres = ____________ lb/yr

Sample Problem 3

WORKSHEET 5 Summary of Results

Manure Source	1. Available manure (Worksheet 2) quantity/year wet	1. dry	2. Agronomic land application rate (Worksheet 3) (line 4) rate/acre wet	2. dry
Solids (bunker)	31,680 tons	5700 tons	411 tons/acre	7.4 tons/acre
Runoff (corn)	4,950,000 gal or 182 acre-inch		1.3 in/acre	
Solids (daily)	56,500 tons	7200 tons	17.0 tons/acre	2.2 tons/acre
Runoff (grass)	4,960,000 gal or 182 acre-inch		1.3 in/acre	

Manure Source	3. Supplemental fertilizer required (Wrksht. 3) (line 5b) lb/acre	4. Land application area required (Worksheet 3) (line 6b) acres
Solids (bunker)	90 lb/acre	771 acres
Runoff (corn)	143 lb/acre	141 acres
Solids (daily)	0 lb/acre	3270 acres
Runoff (grass)	18 lb/acre	3420 acres

5. Quantity of runoff from land application site (Worksheet 4) (part 6e)

Surface applied .... < 2760 acre-in (6e.1)

Soil incorporated....... 1824 acre-in (6e.2)

6. N from manure transported in runoff from land (Worksheet 4, part 7)

Surface applied........ < 15,720 lb/yr (7a. 5)

Soil incorporated...... 912 lb/yr (7b. 2)

7. P from manure transported in runoff from land (Worksheet 4, part 8)

Surface applied....... < 3750 lb/yr (8a.5)

Soil incorporated..... 183 lb/yr (8b.2)

8. COD from manure transported in runoff from land (Worksheet 4, part 9)

Surface applied............. < 246,000 lb/yr (9a.5)

Soil incorporated............ 22,800 lb/yr (9b.2)

9. Percolation of N below 4-foot root zone (Worksheet 4) (part 10)

Fall applied........... 10,710 lb/yr (10c.)

Spring applied........ 0 lb/yr (10d.)

Sample Problem 4

WORKSHEET 1 Problem Evaluation

1. What is the manure-management system problem?

   A farmer in Lancaster County, Nebraska, wants to know how many acres of land he needs to apply swine waste at agronomic rates to supply nitrogen to grain sorghum. He must avoid creating a salt problem, and minimize environmental pollution.

2. What is known about the current system, i.e., location, climate, livestock or poultry type, animal numbers, etc.?

   400 swine, yearly capacity
   Confined housing, anaerobic pit
   Conservation practices terraced
   Sorghum (120 bu/acre yield) used for grain, not irrigated
   Topography is rolling, loess-drift hills; Sharpsburg silty clay loam;
   Wastes are surface-applied and incorporated by disking.
   Leaching estimated at 3 inches. Can use 6 inches of irrigation.
   Hydrologic soils group B
   Soil Test indicates 10 lb N available.

   Waste analysis: 82% water, wet basis; 4% N, dry basis; sum of percentages of K, Ca, Mg, Na = 7.0%

3. What answers should the worksheets provide?

   Limitations for application rates for stored slurry acres of cropland need for waste application minimal environmental pollution.

4. With the above information completed, proceed to Worksheet 2.

Sample Problem 4

WORKSHEET 7. Determining Quantities of Livestock or Poultry Manures Available for Land Application

1. Location (LRA, Figure 4, page 8) 106
2. Climate (Figure 6, page 11) .... ___cold; ✓cool; ___warm; ___hot; ✓humid; ___arid;
3. Animal type .... swine
4. Number of animals (one-time capacity or inventory number) 400
5. Management system (Problem description) .... housed confinement with pit storage
6. Check manure source and form and fill in the blanks below using local data for characteristics

Manure Source and Form				Wet Quantity			Dry Weight		
Source[1] (Table 7, page 22)	Form: Solid	Form: Slurry	Form: Liquid	Wet weight or gal/animal/year [2]	x Animal number	= Annual wet quantity	Dry weight/animal/year	x Animal number	= Annual dry weight [4]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Barn .... Pack ___ Pit ✓ Floor ___		✓		0.833	400	333 tons	0.15 tons	400	60 tons
Paved lot									
Unpaved lot									
Runoff (Tables 5 and 6, pages 20 & 21; text, page 20)									
Effluent [4]									
Settled Solids [4]							(	)[4]	
Stored Manure									
Holding pond (agitated)[3]									
Effluent [4]									
Settled Solids [4]							(	)[4]	
Anaerobic lagoon (agitated) [3] .									
Effluent [4]									
Settled Solids [4]							(	)[4]	
Aerobic lagoon (agitated) [3] ...									
Effluent [4]									
Settled Solids [4]							(	)[4]	
Oxidation ditch									
Oxidation ditch overflow holding pond (agitated) .... [3]									
Effluent [4]									
Settled Solids [4]							(	)[4]	
Other									
....									
....									

---

[1] Include all sources and forms of manures for a particular system.

[2] Liquids are expressed in gallons per animal per year; to convert gallons to acre-inches, divide by 27,150 gal/acre-in; slurry and solids are expressed in tons/animal/year.

[3] If holding ponds or lagoons are not agitated when pumped out, or a debris basin is used to separate solids, enter wet quantity under effluent.

[4] If ponds, lagoons, etc., are not agitated, estimate dry weight effluent and settled solids as follows: Settled solids dry weight = total runoff solids times 0.6. If available, use reliable local estimates of the fraction of total runoff solids that can be expected to settle out.

Sample Problem 4

WORKSHEET 3 **Determining Application Rate of Livestock or Poultry Manure to Land**[1]

1. Location (LRA, Figure 4, page 8) 106

Terraces

1a Topographic Features .... Flat [✓ Rolling] Steep Slope

1b Conservation Practices .... [✓ Yes] No Unknown

1c Hydrologic Soil Group (Section 4, page 28; Table 17, page 45) .... A [✓ B] C D

1d Irrigation .... Yes [✓ No]

If yes:

1d.1 Water Source .... Ground water Surface water

1d.2 Water Electrical Conductivity (EC) (mmhos/cm) ....

1e Climate (Figure 6, page 11) .... cold; [✓ cool;] warm; hot; arid; [✓ humid]

Maximum (Average) Annual Precipitation (Table 6, page 21) .. 36 inches/year

Surface disced

1f Application time [circle most probable months] (Table 9, page 27) J F [✓ M] A M J J A S O N [✓ D] (Every 3-4 months)

1g Method of application .... Surface Soil incorporate Unknown

1h Type of cropping system. sorghum .... Grass Small grain [✓ Row] Plowed field

1i Other considerations:

1i.1 Is land plowed .... Yes [✓ No] Unknown

1i.2 If yes, when .... Spring Fall Unknown

2. Agronomic Application Rates

2a N content of crop[1] (Table 10, page 29) Grain + stover 2 x table value for 60 bu/acre 230 lb/acre

2b N available in soil (soil test)[2] .... 10 lb/acre

2c N needed from manure

2c.1 Needed [N content of crops (line 2a) - N available in soil (line 2b)] .... 220 lb/acre

2c.2 N needed from manure (line 2c.1 divided by 2)[3] .... 110 lb/acre

2d Recommended Dry and Wet Rates (Table 7, page 22)

Manure Source (Worksheet 2) (1)	Percent N (local analysis or Table 7, page 22) (2)	Manure needed to supply 100# N (Table 14. p. 33, or calculated vol., p. 33) (3) rate/acre	Multiplication Factor (Table 12, page 31) (4)	Recommended Dry Rate or Volume (col. 3 x col. 4 x manure N / 100) (5) rate/acre	Recommended Wet Rate (calculate from col. 5)[4] (6) rate/acre
Swine pit	4.0 (analysis 82% water wet basis; 4% N, dry basis)	1.4	1.33	2.05 tons $\left(\frac{1.4 \times 1.33 \times 110}{100}\right)$	11.4 tons

See footnotes at end of Worksheet.

Worksheet 3 (continued).

3. Loading rate limitations

Salinity limits

Manure source (Worksheet 2) Swine pit ____ ____

3a Manure salt content (%) or Runoff electrical conductivity (EC in mmhos/cm) (Table 7, p. 22) 14 % ____ % ____ mmhos/cm

3b Salinity calculations

3b.1 Leaching required for soil for low salinity status (Text, pages 32-35) 3 inches ____ inches

3b.2 Irrigation water to dilute runoff (Figures 15 and 16, pages 37 and 38) ____ inches/ ____ inches of runoff

3c Nonirrigated land limiting application rate (Figures 13 and 15, pages 36 and 37) 7 tons/acre (dry) ____ tons/acre (dry) ____ inches/acre

3d Irrigated land limiting application rate (Figures 13 and 15, pages 36 and 37) ____ tons/acre (dry) ____ tons/acre (dry) ____ inches/acre-ft irrigation

3e Crop tolerance to salinity (Table 15, page 35) ____ very high; ____ high; ✓ medium; ____ low;

Other limitations (grass tetany, fat necrosis, etc.) Explain: ____

Manure Source.............. Swine pit ____ ____

4. The limited application rate is the lesser quantity shown on lines 2d or 3c (nonirrigated) or 3d (irrigated) .... 2.05 tons/acre (dry) ____ tons/acre (dry) ____ in/acre ____ in/acre-ft irrigation

5. Because of the limited application rate, determine the supplemental fertilizer required:

5a Actual N applied in manure: limiting application rate (lines 2d, 3c, or 3d) x 100 / adjusted app. rate (line 2d or col. 3 x col. 4) = Actual N applied

Manure Source Swine pit 2.05 x 100 / 1.86 = 110 lb N/acre

1.4 x 1.33 = 1.86 ____ x 100 / ____ = ____ lb N/acre

____ ____ x 100 / ____ = ____ lb N/acre

5b Supplemental N required: N needed (line 2c.1) - N applied (line 5a) = supplemental N required

Manure Source Swine pit 220 - 110 = 110 lb N/acre

no problem with salinity

____ ____ - ____ = ____ lb N/acre

____ ____ - ____ = ____ lb N/acre

See footnotes at end of Worksheet.

(continued)

Worksheet 3. (conclusion)

6. Application area

6a

Manure source (from worksheet 2)	Available quantity (worksheet 2)		Application rate (line 4) (rate/acre)		Area required (acres)
Swine pit	60 tons (dry)	÷	2.05	=	29.3 acres
				=	
				=	

6b Total application area (add all areas required for each manure source) = 29.3 acres

---

[1] Nitrogen required by crops must be adjusted to correspond to expected yields and N content for the area and soils if different from Table 10.

[2] Contact County Extension and Soil Conservation Service offices for local information. Use Agriculture Handbook 296 for general information for Land Resource Areas.

[3] Assuming one-half of the N needed is to come from the manure. Any other convenient fraction could be assigned to the quantity of N to be derived from the manure source. See text, page 30 .

[4] Recommended wet weight quantities are expressed in tons of manure. To obtain gallons of manure, multiply by 240 $\left[\frac{2000\ \text{lb}}{1\ \text{ton}} \times \frac{1\ \text{gal}}{8.34\ \text{lb}} = \frac{240\ \text{gal}}{1\ \text{ton}}\right]$ To convert gal/acre to in/acre, divide by 27,150 gal/acre-in. To calculate wet weight

[5] From dry weight of solids, divide column 5 by the fractional dry weight.

Sample Problem 4

WORKSHEET 4. Environmental Effects of Manure on Application Site

1. Location (Land Resource Area, Fig. 4, page 8) 106

2. Application Site
   - 2a Land use (surrounding area) .... ✓ Agricultural ___ Recreation ___ Urban Development
   - 2b Map of area .... ✓ Yes ___ No
     - 2b.1 Distance from waterways, lake, streams .... 1-2 miles
     - 2b.2 Distance from neighbors, city, etc .... 1/2-1 miles
     - 2b.3 Will prevailing winds cause an odor nuisance? ... ✓ Yes ___ No
     - 2b.4 Are wells on the application site used by animals or humans? .... ___ Yes ✓ No
   - 2c Zoning requirements .... ___ Yes ✓ No

3. Method of application .... ✓ Surface applied ___ Soil incorporated

4. Cropping system(s) used .... ___ Grass ___ Small grain ✓ Row ___ Plowed field

5. Are conservation practices used or planned? .... ✓ Yes ___ No ___ Unknown

6. Quantity of runoff from application site (without manure applied)
   - 6a Annual runoff (Table 17, p. 45) .... 2.7 inches
   - 6b Percent by snowmelt (Table 17, p. 45) .... 10 percent
   - 6c Percent by rainfall = 100% - snowmelt% .... 90 percent
   - 6d Application site area (Line 6b, Worksheet 3) .... 29.3 acres
   - 6e Annual runoff from application site:

6e.1 Surface applied

Snowmelt runoff = annual runoff (inches) x fraction by snowmelt x application site (acres)
= 2.7 x 0.10 x 29.3 x (0.8) = 6.3 acre-in

Rainfall runoff = annual runoff (inches) x fraction by rainfall x application site (acres)
= 2.7 x 0.90 x 29.3 x (.95) = 67.6 acre-in

Total runoff = snowmelt runoff + rainfall runoff
= 6.3 + 67.6 = 73.9 acre-in

6e.2 Soil incorporated

Snowmelt runoff = annual runoff (inches) x fraction by snowmelt x application site area (acres)
= 2.7 x 0.10 x 29.3 = 7.9 acre-in

Rainfall runoff = annual runoff (inches) x fraction by rainfall x application site area (acres)
= 2.7 x 0.90 x 29.3 = 71.2 acre-in

Total runoff = snowmelt runoff + rainfall runoff
= 7.9 + 71.2 = 79.1 acre-in

Worksheet 4 (continued).

7. Estimated quantity of N transported in runoff

	Cropping System			
	Grass	Small grain	✓ Row	Plowed field
7a Surface-Applied Manure:				
7a.1 N transported annually (Table 19, p. 51).........	____ lb/acre	____ lb/acre	1.6 lb/acre	____ lb/acre
7a.2 increase due to manure (Table 22, p. 60).........	____ lb/acre	____ lb/acre	0.9 lb/acre	____ lb/acre
7a.3 maximum short term (Table 25, p. 68)...........	____ lb/acre	____ lb/acre	0.73 lb/acre	____ lb/acre
7a.4 maximum short term transport is from:(Tbl.25.....	____ snowmelt		____ 4-week rainfall	

7a.5 total N transported from application site = annual N transported (7a.1) x application site area(line 6d)
= 1.6 lb/acre x 29.3 acres = 46.9 lb/yr

7b Soil-Incorporated Manure:

7b.1 N transported annually = N transported annually w/manure applied (line 7a.1)- increase due to manure (line 7a.2)
= 1.6 lb/acre - 0.9 lb/acre = 0.7 lb/acre

7b.2 Total N transported from application site = N transported annually (line 7b.1) x application site area (line 6d)
0.7 lb/acre x 29.3 acres = 2.05 lb/yr

{for comparison only

8. Estimated quantity of P transported in runoff

	Cropping System			
	Grass	Small grain	✓ Row	Plowed field
8a Surface-Applied Manure:				
8a.1 P transported annually (Table 20, p. 54).....	____ lb/acre	____ lb/acre	0.4 lb/acre	____ lb/acre
8a.2 increase due to manure (Table 23, p. 62).....	____ lb/acre	____ lb/acre	0.3 lb/acre	____ lb/acre
8a.3 maximum short term (Table 26, p. 71).........	____ lb/acre	____ lb/acre	0.18 lb/acre	____ lb/acre
8a.4 maximum short term transport is from:(Tbl. 26)	____ snowmelt		✓ 4-week rainfall	

8a.5 total P transported from application site = annual P transported (8a.1) x application site area (line 6d)
= 0.4 lb/acre x 29.3 acres = 11.7 lb/yr

8b Soil-Incorporated Manure:

8b.1 P transported annually = P transported annually w/ manure applied (line 8a.1) - increase due to manure (line 8a.2)
= 0.4 lb/acre - 0.3 lb/acre = 0.1 lb/acre

8b.2 Total P transported from application site = P transported annually (line 8b.1) x application site area (line 6d)
= 0.1 lb/acre x 29.3 acres = 2.9 lb/yr

{for comparison only

Worksheet 4 (continued).

9. Estimated quantity of COD transported in runoff

	Cropping System			
9a Surface-Applied Manure:	____ Grass	____ Small grain	✓ Row	____ Plowed field
9a.1 COD transported annually (Table 21, p. 56).	____ lb/acre	____ lb/acre	20.0 lb/acre	____ lb/acre
9a.2 increase due to manure (Table 24, p. 65)..	____ lb/acre	____ lb/acre	8.0 lb/acre	____ lb/acre
9a.3 maximum short term (Table 27, p. 74).....	____ lb/acre	____ lb/acre	9.0 lb/acre	____ lb/acre
9a.4 maximum short term transport is from: (Tbl. 27)	____ snowmelt		✓ 4-week rainfall	

9a.5 total COD transport from application site = annual COD transport (9a.1) x application site area (line 6d)

= 20.0 lb/acre x 29.3 acres = 586 lb/yr

for comparison only

9b Soil-Incorporated Manure:

9b.1 COD transported annually = COD transported annually w/man. applied (9a.1) - increase due to manure (9a.2)

= 20.0 lb/acre - 8.0 lb/acre = 12.0 lb/acre

9b.2 Total COD transported from application site = COD transported annually (9b.1) x application site area (line 6d)

= 12.0 lb/acre x 29.3 lb/acre = 352 lb/yr

10. Percolation below the 4 foot soil profile (potential)

10a. Surface-applied manure (Leaching of N unchanged from land w/o manure applied)

10b. Soil-incorporated manure at agronomic land application rates (Leaching of N unchanged from land w/o manure applied)

10c. Soil-incorporated manure at twice agronomic application rates---Fall application of manure

for comparison only

10c.1 N leached below 4-foot soil profile

$= \text{N leached per 100 lb N crop content (Table 28, p. 77)} \times \frac{\text{N content of crop (Worksheet 3, Line 2a)}}{100}$

= 5.0 x 230 = 11.5 lb/acre

10c.2 N leached from manure application site when manure is fall applied

N leached = N leached (line 10c.1) x application site area (line 6d) =

= 11.5 lb/acre x 29.3 = 337 lb/yr

Worksheet 4 (conclusion).

10d Soil-incorporated manure at twice agronomic application rates---Spring application of manure

10d. 1 N leached below 4-foot soil profile

= N leached per 100 lb N crop content (Table 28, page 77) x $\frac{\text{N content of crop (Worksheet 3, Line 2a)}}{100}$

= 0 x $\frac{230}{100}$ = 0 lb/ac

for comparison only

10d 2 N leached from manure application site when manure is spring applied

N leached = N leached (line 10d.1) x application site area (line 6d) =

= 0 lb/acre x 29.3 acres = 0 lb/yr

Sample Problem 4

WORKSHEET 5 Summary of Results

Manure Source	1. Available manure (Worksheet 2) quantity year wet	dry	2. Agronomic land application rate (Worksheet 3) (line 4) rate/acre wet	dry
Swine pit	333 tons	60 tons	11.4 tons	2.0 tons

Manure Source	3. Supplemental fertilizer required Wrksht. 3) (line 5b) lb/acre	4. Land application area required (Worksheet 3) (line 6b) acres
Swine pit	110	29.3

5. Quantity of runoff from land application site (Worksheet 4) (part 6e)
Surface applied .... 73.9 acre-in (6e.1)
Soil incorporated....... 79.1 acre-in (6e.2)

6. N from manure transported in runoff from land (Worksheet 4, part 7)
Surface applied........ 46.9 lb/yr (7a. 5)
Soil incorporated...... 20.5 lb/yr (7b. 2)

7. P from manure transported in runoff from land (Worksheet 4, part 8)
Surface applied....... 11.7 lb/yr (8a.5)
Soil incorporated..... 2.9 lb/yr (8b.2)

8. COD from manure transported in runoff from land (Worksheet 4. part 9)
Surface applied............ 586 lb/yr (9a.5)
Soil incorporated............ 352 lb/yr (9b.2)

9. Percolation of N below 4-foot root zone (Worksheet 4) (part 10)
Fall applied........... 337 lb/yr (10c.)
Spring applied........ 0 lb/yr (10d.)

BLANK WORKSHEETS

WORKSHEET 1 Problem Evaluation

1. What is the manure-management system problem?

2. What is known about the current system, i.e., location, climate, livestock or poultry type, animal numbers, etc.?

3. What answers should the worksheets provide?

4. With the above information completed, proceed to Worksheet 2.

WORKSHEET 2 Determining Quantities of Livestock or Poultry Manures Available for Land Application

1. Location (LRA, Figure 4, page 8) .... ______
2. Climate (Figure 6, page 11) .... ___cold; ___cool; ___warm; ___hot; ___humid; ___arid.
3. Animal type .... ______
4. Number of animals (one-time capacity or inventory number) ______
5. Management system (Problem description) .... ______
6. Check manure source and form and fill in the blanks below using local data for characteristics.

Manure Source and Form				Wet Quantity			Dry Weight		
Source[1/] (Table 7, page 22)	Form: Solid	Form: Slurry	Form: Liquid	Wet weight or gal/ animal/ year [2/]	x Animal number	= Annual wet quantity	Dry weight/ animal/ year	X Animal number	= Annual dry weight [4/]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Barn	___	___	___	______	x ______	= ______	______	x ______	= ______
Pack ____									
Pit ____									
Floor ____									
Paved lot	___	___	___	______	x ______	= ______	______	x ______	= ______
Unpaved lot	___	___	___	______	x ______	= ______	______	x ______	= ______
Runoff (Tables 5 and 6, pages 20 & 21; text, page 20)	___	___	___	______	x ______	= ______	______	x ______	= ______
Effluent [4/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Settled Solids [4/]	___	___	___				(______	x ______)4/	= ______
Stored Manure	___	___	___	______	x ______	= ______	______	x ______	= ______
Holding pond (agitated)[3/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Effluent [4/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Settled Solids [4/]	___	___	___				(______	x ______)4/	= ______
Anaerobic lagoon (agitated) [3/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Effluent [4/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Settled Solids [4/]	___	___	___				(______	x ______)4/	= ______
Aerobic lagoon (agitated) [3/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Effluent [4/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Settled Solids [4/]	___	___	___				(______	x ______)4/	= ______
Oxidation ditch	___	___	___	______	x ______	= ______	______	x ______	= ______
Oxidation ditch overflow holding pond (agitated) .... [3/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Effluent [4/]	___	___	___	______	x ______	= ______	______	x ______	= ______
Settled Solids [4/]	___	___	___				(______	x ______)4/	= ______
Other	___	___	___	______	x ______	= ______	______	x ______	= ______
______........................	___	___	___	______	x ______	= ______	______	x ______	= ______
______........................	___	___	___	______	x ______	= ______	______	x ______	= ______

---

[1] Include all sources and forms of manures for a particular system.

[2] Liquids are expressed in gallons per animal per year; to convert gallons to acre-inches, divide by 27,150 gal / acre-in; slurry and solids are expressed in tons/animal/year.

[3] If holding ponds or lagoons are not agitated when pumped out, or a debris basin is used to separate solids, enter wet quantity under effluent.

[4] If ponds, lagoons, etc., are not agitated, estimate dry weight effluent and settled solids as follows: Settled solids dry weight = total runoff solids times 0.6. If available, use reliable local estimates of the fraction of total runoff solids that can be expected to settle out.

WORKSHEET 3 Determining Application Rate of Livestock or Poultry Manure to Land [1]

1. Location (LRA, Figure 4, page 8) .... ________ ________ ________ ________

1a Topographic Features .... ________ Flat ________ Rolling ________ Steep Slope

1b Conservation Practices .... ________ Yes ________ No ________ Unknown

1c Hydrologic Soil Group (Section 4, page 28; Table 17, page 45) ________ A ________ B ________ C ________ D

1d Irrigation .... ________ Yes ________ No

If yes:

1d.1 Water Source .... ________ Ground water ________ Surface water

1d.2 Water Electrical Conductivity (EC) (mmhos/cm)........ ________ ________

1e Climate (Figure 6, page 11)........................ ______cold; ______cool; ______warm; ______hot; ______arid; ______humid

Maximum (Average) Annual Precipitation (Table 6, page 21).. ______inches/year

1f Application time [circle most probable months] (Table 9, page 27) J F M A M J J A S O N D

1g Method of application .... ______ Surface ________ Soil incorporate ________Unknown

1h Type of cropping system........................ ______ Grass ______Small grain ______Row ______Plowed field

1i Other considerations:

1i.1 Is land plowed .... ______ Yes ________ No ______ Unknown

1i.2 If yes, when .... ______ Spring ________ Fall ______ Unknown

2. Agronomic Application Rates

2a N content of crop[1] (Table 10, page 29)........................ ______ lb/acre

2b N available in soil (soil test)[2] .... ______ lb/acre

2c N needed from manure

2c.1 Needed [N content of crops (line 2a) - N available in soil (line 2b)] .... ______lb/acre

2c.2 N needed from manure (line 2c.1 divided by 2)[3]........................ ______lb/acre

2d Recommended Dry and Wet Rates (Table 7, page 22)

Manure Source (Worksheet 2)	Percent N (local analysis or Table 7, page 22)	Manure needed to supply 100# N (Table 14, p. 33, or calculated vol., p. 32)	Multiplication Factor (Table 12, page 31)	Recommended Dry Rate or Volume (col. 3x col. 4 x $\frac{\text{manure N}}{100}$)	Recommended Wet Rate (calculate from col. 5)[4]
(1)	(2)	(3)	(4)	(5)	(6)
		rate/acre		rate/acre	rate/acre
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________

See footnotes at end of Worksheet.

Worksheet 3 (continued).

3. Loading rate limitations

Salinity limits

Manure source (Worksheet 2) ______ ______ ______

3a Manure salt content (%) or Runoff electrical conductivity (EC in mmhos/cm) (Table 7, p. 22) ______% ______% ______mmhos/cm

3b Salinity calculations

3b.1 Leaching required for soil for low salinity status (Text, pages 32-35) ______ inches ______ inches

3b.2 Irrigation water to dilute runoff (Figures 15 and 16, pages 37 and 38) ______ inches/ ______ inches of runoff

3c Nonirrigated land limiting application rate (Figures 13 and 15, pages 36 and 37) ______tons/acre (dry)______tons/acre (dry)______inches/acre

3d Irrigated land limiting application rate (Figures 13 and 15, pages 36 and 37) ______tons/acre (dry)______tons/acre (dry)______inches/acre-ft irrigation

3e Crop tolerance to salinity (Table 15, page 35) ______very high; ______high; ______ medium; ______ low;

Other limitations (grass tetany, fat necrosis, etc.) Explain: ______

Manure Source............... ______ ______ ______ .

4. The limited application rate is the lesser quantity shown on lines 2d or 3c (nonirrigated) or 3d (irrigated) ....______tons/acre (dry)______tons/acre (dry)______in/acre ______in/acre-ft irrigation

5. Because of the limited application rate, determine the supplemental fertilizer required:

5a Actual N applied in manure: limiting application rate (lines 2d, 3c, or 3d) x 100 / adjusted app. rate (line 2d ÷ or col. 3 x col. 4) = Actual N applied

Manure Source ______ ______ x ______100______ = ______lb N/acre

______ ______ x ______100______ = ______lb N/acre

______ ______ x ______100______ = ______lb N/acre

5b Supplemental N required: N needed (line 2c.1) - N applied (line 5a) = supplemental N required

Manure Source ______ ______ - ______ = ______lb N/acre

______ ______ - ______ = ______lb N/acre

______ ______ - ______ = ______lb N/acre

See footnotes at end of Worksheet.

(continued)

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Worksheet 3. (conclusion).

6. Application area

6a

Manure source (from Worksheet 2)	Available quantity (Worksheet 2)	Application rate (line 4) (rate/acre)	= Area required (acres)
________	________	________	= ________
________	________	________	= ________
________	________	________	= ________

6b Total application area (add all areas required for each manure source) = ________

---

[1] Nitrogen required by crops must be adjusted to correspond to expected yields and N content for the area and soils if different from Table 10.

[2] Contact County Extension and Soil Conservation Service offices for local information. Use Agriculture Handbook 296 for general information for Land Resource Areas.

[3] Assuming one-half of the N needed is to come from the manure. Any other convenient fraction could be assigned to the quantity of N to be derived from the manure source. See text, page 30 .

[4] Recommended wet weight quantities are expressed in tons of manure. To obtain gallons of manure, multiply by 240 $\left[\frac{2000\text{ lb}}{1\text{ ton}} \times \frac{1\text{ gal}}{8.34\text{ lb}} = \frac{240\text{ gal}}{1\text{ ton}}\right]$. To convert gal/acre to in/acre, divide by 27,150 gal/acre-in. To calculate wet weight from dry weight of solids, divide column 5 by the fractional dry weight.

WORKSHEET 4. Environmental Effects of Manure on Application Site

1. Location (Land Resource Area, Fig. 4, page 8)............ ______________________________

2. Application Site

2a Land use (surrounding area) .... ______Agricultural ______ Recreation ______Urban Development

2b Map of area .... ______Yes ______ No

2b.1 Distance from waterways, lake, streams.......... ______miles

2b.2 Distance from neighbors, city, etc.............. ______miles

2b.3 Will prevailing winds cause an odor nuisance?... ______Yes ______ No

2b.4 Are wells on the application site used by animals or humans? .... ______Yes ______ No

2c Zoning requirements .... ______Yes ______ No

3. Method of application.................................... __________Surface applied __________Soil incorporated

4. Cropping system(s) used.................................. ______Grass ______Small grain ______Row ______Plowed field

5. Are conservation practices used or planned? .... ______Yes ____No ______Unknown

6. Quantity of runoff from application site (without manure applied)

6a Annual runoff (Table 17, p. 45).................... ______inches

6b Percent by snowmelt (Table 17, p. 45)................ ______percent

6c Percent by rainfall = 100% - snowmelt% .... ______percent

6d Application site area (Line 6b, Worksheet 3)....... ______acres

6e Annual runoff from application site:

6e.1 Surface applied

Snowmelt runoff = annual runoff (inches) x fraction by snowmelt x application site (acres)

= ______________ x ______________ x ______________ x (0.8) = ______acre-in

Rainfall runoff = annual runoff (inches) x fraction by rainfall x application site (acres)

= ______________ x ______________ x ______________ x (.95) = ______acre-in

Total runoff = snowmelt runoff + rainfall runoff

= __________ + __________ = ________acre-in

6e.2 Soil incorporated

Snowmelt runoff = annual runoff (inches) x fraction by snowmelt x application site area (acres)

= ______________ x ______________ x ______________ = ________acre-in

Rainfall runoff = annual runoff (inches) x fraction by rainfall x application site area (acres)

= ______________ x ______________ x ______________ = ________acre-in

Total runoff = snowmelt runoff + rainfall runoff

= __________ + __________ = ________acre-in

Worksheet 4 (continued).

7. Estimated quantity of N transported in runoff

	Cropping System			
7a Surface-Applied Manure.	____ Grass	____ Small grain	____ Row	____ Plowed field
7a.1 N transported annually (Table 19, p. 51).........	____ lb/acre	____ lb/acre	____ lb/acre	____ lb/acre
7a.2 increase due to manure (Table 22, p. 60).........	____ lb/acre	____ lb/acre	____ lb/acre	____ lb/acre
7a.3 maximum short term (Table 25, p. 68)...........	____ lb/acre	____ lb/acre	____ lb/acre	____ lb/acre
7a. 4 maximum short term transport is from:(Tbl.25.....	____ snowmelt		____ 4-week rainfall	

7a. 5 total N transported from application site = annual N transported (7a.1) x application site area(line 6d)

= ____ lb/acre x ____ acres = ____ lb/yr

7b Soil-Incorporated Manure:

7b.1 N transported annually = N transported annually w/manure applied (line 7a. 1)- increase due to manure (line 7a.2)

= ____ lb/acre - ____ lb/acre = ____ lb/acre

7b.2 Total N transported from application site = N transported annually (line 7b.1) x application site area (line 6d)

____ lb/acre x ____ acres = ____ lb/yr

8. Estimated quantity of P transported in runoff

	Cropping System			
8a Surface-Applied Manure:	____ Grass	____ Small grain	____ Row	____ Plowed field
8a.1 P transported annually (Table 20, p. 54).....	____ lb/acre	____ lb/acre	____ lb/acre	____ lb/acre
8a.2 increase due to manure (Table 23, p. 62).....	____ lb/acre	____ lb/acre	____ lb/acre	____ lb/acre
8a.3 maximum short term (Table 26, p. 71).........	____ lb/acre	____ lb/acre	____ lb/acre	____ lb/acre
8a.4 maximum short term transport is from:(Tbl. 26)	____ snowmelt		____ 4-week rainfall	

8a.5 total P transported from application site = annual P transported (8a.1) x application site area (line 6d)

= ____ lb/acre x ____ acres = ____ lb/yr

8b Soil-Incorporated Manure:

8b.1 P transported annually = P transported annually w/ manure applied (line 8a.1) - increase due to manure (line 8a.2)

= ____ lb/acre - ____ lb/acre = ____ lb/acre

8b.2 Total P transported from application site = P transported annually (line 8b.1) x application site area (line 6d)

= ____ lb/acre x ____ acres = ____ lb/yr

Worksheet 4 (continued).

9. Estimated quantity of COD transported in runoff

	Cropping System			
9a Surface-Applied Manure:	______ Grass	______ Small grain	______ Row	______ Plowed field
9a.1 COD transported annually (Table 21, p. 56).	______ lb/acre	______ lb/acre	______ lb/acre	______ lb/acre
9a.2 increase due to manure (Table 24, p. 65)..	______ lb/acre	______ lb/acre	______ lb/acre	______ lb/acre
9a.3 maximum short term (Table 27, p. 74).....	______ lb/acre	______ lb/acre	______ lb/acre	______ lb/acre

9a.4 maximum short term transport is from: (Tbl. 27) ______ snowmelt ______ 4-week rainfall

9a.5 total COD transport from application site = annual COD transport (9a.1) x application site area (line 6d)

= ______ lb/acre x ______ acres = ______ lb/yr

9b Soil-Incorporated Manure:

9b.1 COD transported annually = COD transported annually w/man. applied (9a.1) - increase due to manure (9a.2)

= ______ lb/acre - ______ lb/acre = ______ lb/acre

9b.2 Total COD transported from application site = COD transported annually (9b.1) x application site area (line 6d)

= ______ lb/acre x ______ lb/acre = ______ lb/yr

10. Percolation below the 4 foot soil profile (potential)

10a. Surface-applied manure (Leaching of N unchanged from land w/o manure applied)

10b. Soil-incorporated manure at agronomic land application rates (Leaching of N unchanged from land w/o manure applied)

10c. Soil-incorporated manure at twice agronomic application rates---Fall application of manure

10c.1 N leached below 4-foot soil profile

$= \text{N leached per 100 lb N crop content (Table 28, p. 77)} \times \frac{\text{N content of crop (Worksheet 3, Line 2a)}}{100}$

= ______ x ______ = ______ lb/acre

10c.2 N leached from manure application site when manure is fall applied

N leached = N leached (line 10c.1) x application site area (line 6d) =

= ______ lb/acre x ______ = ______ lb/yr

Worksheet 4 (conclusion).

10d. Soil-incorporated manure at twice agronomic application rates---Spring application of manure

10d.1 N leached below 4-foot soil profile

= N leached per 100 lb N crop content (Table 28, page 77) x $\frac{\text{N content of crop (Worksheet 3, Line 2a)}}{100}$

= ____________________ x $\frac{\text{____________________}}{100}$ = __________ lb/ac

10d.2 N leached from manure application site when manure is spring applied

N leached = N leached (line 10d.1) x application site area (line 6d) =

= __________ lb/acre x ______________ acres = __________ lb/yr

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WORKSHEET 5 Summary of Results

Manure Source	1. Available manure (worksheet 2) quantity/year wet	 dry	2. Agronomic land application rate (Worksheet 3) (line 4) rate acre^{-1} wet	 dry
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________

Manure Source	3. Supplemental fertilizer required Wrksht. 3) (line 5b) lb/acre	4. Land application area required (Worksheet 3) (line 6b) acres
________	________	________
________	________	________
________	________	________

5. Quantity of runoff from land application site (Worksheet 4) (part 6e)

Surface applied .... ________ acre-in (6e.1)

Soil incorporated....... ________ acre-in (6e.2)

6. N from manure transported in runoff from land (Worksheet 4, part 7)

Surface applied........ ________ lb/yr (7a. 5)

Soil incorporated...... ________ lb/yr (7b. 2)

7. P from manure transported in runoff from land (Worksheet 4, part 8)

Surface applied....... ________ lb/yr (8a.5)

Soil incorporated..... ________ lb/yr (8b.2)

8. COD from manure transported in runoff from land (Worksheet 4, part 9)

Surface applied.............. ________ lb/yr (9a.5)

Soil incorporated........... ________ lb/yr (9b.2)

9. Percolation of N below 4-foot root zone (Worksheet 4) (part 10)

Fall applied........... ________ lb/yr (10c.)

Spring applied........ ________ lb/yr (10d.)